2.8 SURFACE WATER HYDROLOGY

2.8.1 Streams and Rivers

The Former Mine Area is located within the Rainy Creek watershed, an area of approximately 17.8 square miles. **Figure 2-5a** shows the Rainy Creek watershed, the main surface water features within the boundary, and the relationship of the surface water features to mined features. In addition, **Figure 2-5a** shows the Water-Use Classifications for the primary streams and associated tributaries within the Rainy Creek Watershed (see ARM 17.30.609 for further clarification on Water-Use Classifications provided in EPA, 2015b).

Rivers and creeks in the OU3 Study Area have been classified under one of three classification standards based on their beneficial use, namely A-1, B-1, and C-1 (see ARM 17.30.609). Creeks within the Rainy Creek drainage above the Former Mined Area directly below the KDID but above the Mill Pond (near Well C) are classified as "A-1". Fleetwood Creek and its tributaries, the tributaries to LRC, Carney Creek, and the Kootenai River are classified as "B-1". Lower Rainy Creek (LRC) from just above the Mill Pond to the Kootenai River outlet is classified as "C-1". These three classes and their respective beneficial uses are as follows:

- **Classification A-1 (ARM 17.30.622):** Maintained suitable for drinking, culinary, and food processing purposes after conventional treatment for removal of naturally present impurities; bathing, swimming and recreation; and growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
- **Classification B-1 (ARM 17.30.623):** Maintained suitable for drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.
- **Classification C-1 (ARM 17.30.626):** Maintained suitable for bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.

The differences between the three classifications can be found within some of the specific parameters where A-1 standards are more stringent than B-1 and C-1 standards, and B-1 standards are more stringent than C-1 standards. Classification standards have been adopted to establish maximum allowable changes in surface water quality and to establish a basis for limiting the discharge of pollutants. These ARM standards are available on the Montana Administrative Rules Services website: http://www.mtrules.org/gateway/Subchapterhome.asp?scn=17.30.6. Some of the standards must be maintained as set forth in the standards given in Montana Department of Environmental Quality (MDEQ) Circular DEQ-7 (MDEQ, 2012) and others are set in the ARM itself. Some of the specific parameters contained in the standards include E-coli bacteria, dissolved oxygen (DO), pH, turbidity, temperature, suspended solids, true color, and other parameters (e.g., radionuclides).

Additionally, **Figure 2-5b** presents the Federal Emergency Management Agency (FEMA) floodplain map for Lincoln County Montana. Since the 1970s FEMA has been creating, storing, and updating flood hazard maps for National Flood Insurance Program communities across the United States. Flood Insurance Rate Maps are the primary tool for state and local governments to mitigate the effects of flooding in their communities. To prepare the Flood Maps that illustrate the extent of flood hazard in a flood prone community, FEMA generally conducts engineering

studies referred to as Flood Insurance Studies. Using the information gathered in these studies, FEMA engineers and cartographers delineate Special Flood Hazard Areas on Flood Maps. Special Flood Hazard Areas are subject to inundation by a flood that has a 1-percent or greater chance of being equaled or exceeded during any given year. This type of flood commonly is referred to as the 100-year flood or base flood. A 100-year flood is not a flood that occurs every 100 years; rather the 100-year flood has a 26 percent chance of occurring during a 30-year period. The 100-year flood is a regulatory standard used by Federal agencies and most states, to administer floodplain management programs. The 100-year flood is used by the National Flood Insurance Program as the basis for insurance requirements nationwide.

As presented on **Figure 2-5b**, other than along the Kootenai River and the mouth of Rainy Creek, the OU3 Study Area is within "Zone X", which is described as areas determined to be outside the 500-year floodplain. The Kootenai River and the mouth of Rainy Creek are described as "Zone A", which are areas that are subject to inundation by the one percent annual chance flood event generally determined using approximate methodologies. Because detailed hydraulic analyses have not been performed, no base flood evaluations or flood depths are shown.

Not all of the OU3 Study Area falls within the Rainy Creek watershed. However, the primary surface water bodies in the Former Mine Area are located within the Rainy Creek watershed and are described below.

Rainy Creek. Rainy Creek originates between Blue Mountain and the north fork of Jackson Creek at an elevation of about 5,000 ft. amsl, and descends to an elevation of approximately 2,080 ft. amsl, where it flows into the Kootenai River (Zinner, 1982) (refer to **Figure 2-6** for flow directions). Rainy Creek is perennial and supports a variety of fish and aquatic invertebrates. The average gradient for Rainy Creek is about 12% (Parker and Hudson, 1992) and the banks are well vegetated (MWH, 2007). The KDID was constructed on Rainy Creek west of Vermiculite Mountain. For the purposes of this report, reaches of Rainy Creek above the impoundment are referred to as Upper Rainy Creek (URC), and reaches below the impoundment are referred to as Lower Rainy Creek (LRC). LRC is isolated from upstream migration of fish from the Kootenai River by a hanging culvert and is usually (except in times of high water overflow) isolated from downstream migration of fish from URC by the tailings impoundment. Consequently, it is most likely that the fish population in LRC is largely self-sustaining (EPA, 2014a).

Fleetwood Creek. Fleetwood Creek originates from mountains on the east side of the Former Mine Area at an elevation of approximately 4,200 ft. amsl, flowing westward along the north edge of the Former Mine Area to the tailings impoundment at an elevation of approximately 2,800 ft. amsl, where it is a tributary to Rainy Creek (refer to **Figure 2-6** for flow directions). The average stream gradient for Fleetwood Creek is about 11% (Parker and Hudson, 1992). Fleetwood Creek is approximately 4 to 5 miles in length, is perennial, and provides habitat for fish and aquatic invertebrates in the reach above the Former Mine Area. The portion of Fleetwood Creek that flows through the coarse tailings area is a reach of approximately 0.5 miles, and is devoid of vegetation and habitat. A small ponded area at the edge of the coarse tailings area was identified along Fleetwood Creek during reconnaissance surveys by the EPA in 2007 and is referred to as Fleetwood Pond.

Carney Creek. Carney Creek originates from the mountains on the southeast side of the Former Mine Area at an elevation of approximately 4,400 ft. amsl, flowing westward along the south edge of the Former Mine Area before joining Rainy Creek approximately 3,000 ft. below the tailings impoundment at an elevation of approximately 2,700 ft. amsl (refer to **Figure 2-6** for flow directions). Carney Creek is approximately 2 to 3 miles in length, is perennial, and provides fish

and invertebrate habitat along the south side of the Former Mine Area. Carney Creek flows through Carney Pond, which was formed when mined materials were deposited in the drainage blocking and altering the flow of the creek. The pond is vegetated on both sides and appears to support aquatic invertebrates and amphibians and is frequented by moose. Several small seeps are reported along Carney Creek (Zinner, 1982) and were identified during reconnaissance surveys by the EPA in 2007 and MWH in 2014 (refer to **Figure 2-4a**).

Kootenai River. The Kootenai River flows from southeast to northwest along the south side of the OU3 Study Area (refer to **Figure 2-6** for flow directions). Fleetwood Creek and Carney Creek flow into Rainy Creek, which is a tributary of the Kootenai River. Rainy Creek flows into the Kootenai River at approximately the southwestern corner of the OU3 Study Area (refer to **Figure 1-2**). Flows in the Kootenai River are controlled by the Libby Dam, which was constructed in the late 1960s through the early 1970s as part of the Columbia River development for flood control, power generation, and recreation. Lake Koocanusa is the result of the Libby Dam construction and borders the western edge of the OU3 Study Area (refer to **Figure 1-2**). Daily water outflow records show lowest flows typically occur in March and October at approximately 4,000 cubic ft. per second (cfs) and maximum flows occur in late May/early June at about 26,000 cfs.

The State of Montana's *Final Water Quality Integrated Report* (MDEQ, 2014) provides the federal Clean Water Act (CWA) Section 303(d) listing of water quality limited (i.e., "impaired") or threatened water bodies and reports on the condition of the water bodies under the state's jurisdiction [Section 305(b)]. According to this report (MDEQ, 2014), the Upper Kootenai River, from the Libby Dam to where the Yaak River enters the Kootenai River (approximately six miles north of Troy), is considered "Impaired Waters" due to impacts from hydrostructure flow regulation/modification from upstream impoundments and water temperatures both of which impair the river's designated use to support aquatic life (https://iaspub.epa.gov/waters10/attains_waterbody.control?p_au_id=MT76D001_010&p_cycle=2014&p_state=MT&p_report_type=). Other designated uses including agricultural, primary contact recreation, and a source of drinking water are considered "Good". The report recommends that a Total Maximum Daily Load (TMDL) study is needed to determine how to address these impairments; however, its priority is listed as low on the above referenced website. These impairments are not associated with OU3 or any of the creeks within the OU3 Study Area. Since the probable source of the impairment is listed as the upstream hydrostructure, the TMDL study likely will focus on altering operations or impacts of the hydrostructure. Impacts to remedial actions at OU3 are unlikely, but will not be known until the TMDL study is complete.

Although long-term stream flow records do not exist for the three on-site creeks discussed above, annual stream flow measurements have been collected since 2008 during the freeze-free part of the year, typically March through November. In August 2008, Parshall flumes were permanently installed in two stations along Rainy Creek (LRC-06 and LRC-02), and one station along Carney Creek (CC-02). The locations of the stations are presented on **Figure 2-6**. The flume sizes at these three stations were selected based on the snowmelt runoff flows observed during spring 2008. Twelve-inch Parshall flumes were installed at stations LRC-06 and LRC-02 and a 9-inch flume was installed at station CC-02. A stilling well was attached to each of the flumes to house a pressure transducer for flow rate measurement and recording by an ISCO® Model 6712 portable sampler/data logger. The 2008 through 2015 spring and fall seasonal minimum flow in gallons per minute (gpm), average flow in gpm, maximum flow in gpm, and number of recorded flow measurements are presented in **Table 2-8** and annual discharge graphs are presented in **Figure 2-6.** These data indicate that the highest flows occur during the months of April through

June. A detailed analysis of site hydrology will be presented in the forthcoming Hydrology Report, which will be issued by MWH in 2016.

2.8.2 Ponds

There are four major mine-related ponds within the Former Mine Area that were sampled as part of the RI activities and are summarized below and on **Table 2-9.** There also are several small (less than one acre in size) minor ponds located within the Former Mine Area. These smaller ponds were not sampled as part of the RI and thus are not detailed further below. The major pond locations are presented on **Figure 2-6** and described below. The depth and volume for each of these ponds is not currently known and should be investigated prior to remedial design.

Carney Pond. Carney Pond is located in the Carney Creek drainage, on the south flank of the RCC intrusion and covers approximately two acres. A smaller pond is located on Carney Creek northwest of Carney Pond that is approximately 0.5 acres in size. Carney Pond was formed when the largest of the waste rock piles filled the drainage channel and dammed the creek.

Fleetwood Pond. Fleetwood Pond is on the northeast flank of the coarse tailings pile and was formed when coarse tailings filled the bottom of the original Fleetwood Creek drainage channel, impounding water flow from small upstream seeps and springs. Fleetwood Pond is less than an acre in area and dries up in late summer based on observations made in 2007 and 2008.

Tailings Impoundment. The purpose of the KDID was to store fine tailings slurry produced by the vermiculite wet mill process. The homogeneous embankment dam was raised in several phases between 1973 and 1980 as tailings were continuously deposited. Today the height of the KDID is about 135 ft. measured from the downstream toe to the dam crest. The tailings impoundment occupies approximately 70 acres and receives inflow from both Rainy Creek and Fleetwood Creek. Most of the flow that enters Rainy Creek below the KDID discharges from the underdrain system. The KDID underdrain system is a series of 8-inch to 14-inch steel, corrugated metal and unreinforced concrete pipes that are aligned upstream to downstream and located near the contact between the KDID foundation and embankment material. The underdrain system starts at the starter dam footprint and outlets as a series of drain pipes at the toe of the KDID embankment. A relatively small portion of the flow passes through the KDID in the principal concrete box culvert and chute located on the left abutment.

Mill Pond. The Mill Pond is located about one-half mile downstream of the KDID. The pond is retained by an earthen berm across the channel of Rainy Creek. There is no record of when the Mill Pond was constructed, but it was used to supply re-use water for the milling operation at the mine. The impounded area of Mill Pond is approximately six acres.

2.9 GROUNDWATER AND SURFACE WATER GEOCHEMISTRY EVALUATION

A groundwater and surface water geochemistry evaluation was performed as part of this report in an effort to evaluate potential groundwater, surface water, and seep water interactions within the Former Mine Area. Specific non-asbestos water analytical data are discussed in detail in **Sections 5.1.2** and **5.1.3.** The available non-asbestos water chemistry data (for surface water and groundwater samples) were evaluated using Piper and Stiff diagrams for data from sampling events in 2007, 2008, 2009, and 2015. The Piper diagram is included on **Figure 2-7.** The surface

water and groundwater sample locations utilized for this evaluation and the Stiff diagrams are presented on **Figures 2-8** and **2-9**; the Stiff diagrams are shown in time series in **Appendix C.**

Evaluation of groundwater, surface water, and seep water chemistry data suggest that there is one primary water type and a possible secondary water type at the Former Mine Area. The Piper diagram shown in **Figure 2-7** represents the sample concentrations for each location. The cation composition of the samples (lower left component of the Piper diagram) shows the waters are dominated by calcium (up to approximately 75%) to mixed calcium/magnesium (approximately 40% each). The cations form a continual gradation; however, the anion composition of the samples (lower right component of the Piper diagram) suggests that one sample location, Well E, is an exception with respect to water typing. Bicarbonate (represented as HCO_3+CO_3) makes up 75% or more of the anion composition of the samples from all of the locations, with the exception of Well E. The anion composition of Well E is mixed bicarbonate/sulfate (SO_4) (approximately 50% and 35%, respectively).

The two water types are as follows:

Primary Water Type. Mixed, calcium-magnesium-bicarbonate: relatively high calcium (>40%) and bicarbonate (>80%) with moderate to high magnesium (20% – 40%), low sodium/potassium (<25%), sulfate (<20%) and chloride (<25%). Total Dissolved Solids (TDS) concentrations ranged from 117 milligrams per liter (mg/L) for a sample collected at the Tailing Pond to 864 mg/L for a sample collected at one of the seeps near Carney Creek (CCS-16) and the average concentration was 452 mg/L. TDS represents the total amount of mobile charged ions dissolved in a given volume of water. The TDS concentrations were calculated by summing the major cation and major anion concentration for each location.

Secondary Water Type (Well E). Mixed, calcium-magnesium-bicarbonate-sulfate: high calcium and magnesium (approximately 50% and 45%, respectively), high bicarbonate (50%) and moderate sulfate (approximately 35%). Sodium/potassium and chloride concentrations were less than 15%. The samples from Well E had TDS values that ranged from 511 mg/L to 524 mg/L.

The similarities in the surface water, groundwater, and toe drain water suggest the system is well-connected. The lack of variability in the concentrations of the cations and anions at the Former Mine Area is likely due to the area draining what is essentially a mono-mineralic geologic formation in terms of the range of potential water-rock interactions. As is discussed in **Section 2.6,** the principal bedrock geology, as expressed at the surface, is dominated by the mineral biotite with minor pyrite, followed by vermiculite-pyroxenite (the focus of mineral extraction) and surrounded by a zone of magnetite pyroxenite. In terms of overall geochemical reactivity, the biotite and minor pyrite have the greatest potential to react with groundwater, while the vermiculite could participate in cation-exchange reactions depending on the chemical composition of recharge to groundwater. Most of the calcium and bicarbonate, as depicted by the shape of the Stiff diagrams, implies that the basin rim forming Wallace Formation, which contains calcareous argillite, likely strongly influences the chemistry of ground and surface water observed at the Former Mine Area. As noted, pyrite does occur in the biotite zone and limited oxidation of the pyrite could potentially explain increased sulfate concentrations observed at Well E, which is located in the Former Mine Area. There are no background groundwater data available for comparison to the data from the wells on the Former Mine Area; therefore, the direct influence of the mine on the groundwater concentrations is not currently quantifiable.

The Stiff diagrams shown on **Figures 2-8** and **2-9** correlate well with the Piper diagrams, supporting the conclusion that there is generally one primary water type throughout the Former

Mine Area, with Well E being an exception. In general, the Stiff diagrams have the same shape and are dominated by calcium-bicarbonate. The sizes of the Stiff diagrams are representative of TDS concentrations and it appears samples collected upstream of the KDID (**Figure 2-8**) have lower TDS concentrations than samples collected at or downstream of the KDID. **Figure 2-9** details the KDID area; samples collected from deeper screen intervals of the dual-screened boreholes (BH-01A-1, BH-05A-1, and BH-07A-1) have higher TDS concentrations than in samples from their respective shallow screens. Excluding Well E, there are no major distinguishing characteristics when comparing the Stiff diagrams for creeks, seeps, toe drains, ponds, and the groundwater wells. The creeks generally have lower cation/anion concentrations than the seeps and the ponds at the tailings impoundment; Fleetwood Pond is the exception in that it had the lowest cation/anion concentrations. The Stiff diagrams for the groundwater wells show variable cation/anion concentrations and the concentrations with respect to location at the Former Mine Area are compared below.

In plotting the Stiff diagrams on the Former Mine Area map in **Figures 2-8** and **2-9**, the following was observed:

- Well E is located in the center of the Former Mine Area. Pyrite has been observed in the mined ore body and limited oxidation of pyrite is likely causing the comparatively high sulfate concentration observed in this well.
- Well E also has higher concentrations of potassium than other groundwater locations, which could be associated with release of potassium from biotite as driven by neutralization of the limited acidity generated by pyrite oxidation.
- The samples collected from URC generally have the lowest TDS, which is expected given the limited amount of water-rock interaction that would occur at such a location.
- Surface water samples collected in toe drains, creeks, and seeps down-gradient of the Former Mine Area (e.g., Carney Creek area, toe drains, and LRC) have increased TDS and anion/cation concentrations when compared to samples collected up-gradient (URC) and reflect the influence of groundwater inflow from both the mine area and the other side of the drainage basin.
- Water samples collected at the toe drains have higher cation/anion concentrations than water collected from the tailings impoundment. The toe drain Stiff diagrams more closely resemble the Well C diagram suggesting the toe drain water quality is a mixture of the tailings water and inflowing groundwater.

The 2007, 2008, and 2015 Stiff diagrams (compared in **Appendix C**) are the same general shape for sample events for each sample location as no major changes in major cation and anion concentrations occurred. In general, the samples collected in June 2008 had lower TDS concentrations than the October sampling events (area of the Stiff diagram is indicative of TDS concentration). The increase in TDS concentrations is likely due to a general decrease in runoff from the spring to the fall sampling events and increases in evapo-concentration. The observed late-season increase in TDS likely reflects normal annual climatic variability. The October 2007 sample event generally had a higher TDS concentration than the October 2008 sampling event (when a location was sampled during both events); however, the increase in TDS was not significant enough to imply a change in groundwater contributions or that a different geochemical process occurred. Stiff diagrams for samples from the tailings pond (TP) and Mill Pond (MP) detail higher TDS concentrations in 2015 when compared to 2007 and 2008.

2.10 ECOLOGICAL SETTING

This section briefly discusses the biological resources in and around the OU3 Study Area. Much of the text is taken from the *Final Asbestos BERA* (EPA, 2014a) and the *Final Non-Asbestos BERA* (CDM Smith, 2013c), which present detailed analysis of the OU3 Study Area ecology.

2.10.1 TERRESTRIAL HABITATS AND TREE SPECIES

The Former Mine Area is disturbed by past mining activity and some areas remain sparsely or non-vegetated. Outside the Former Mine Area, most of the OU3 Study Area is forested, with only 4% of the land being classified as non-vegetated (U.S. Department of Agriculture Forest Service Region 1 [USDAFSR1], 2008). Data for the Kootenai National Forest indicate Douglas fir forest type is the most common, covering nearly 35% of the National Forest land area within the OU3 Study Area. Next in abundance are the Lodgepole pine forest and Spruce-Fir forest types at 17% each, and the Western Larch forest type at 11%. Other tree species reported in the area are the Black Cottonwood (*Populus trichocarpa*), Quaking Aspen (*Populus tremuloides*), Western Paper Birch (*Betula papyrifera var. occidentalis*) and Pacific Yew (*Taxus brevifolia*) (USDAFSR1, 2008).

A vegetative-cover map based on remote sensing data was developed by the Wildlife Spatial Analysis Lab at the University of Montana in Missoula (Fisher *et al.,* 1998). Based on this mapping, the vegetative cover around the Former Mine Area is predominantly Douglas fir, Lodgepole pine, and mixed mesic forest as presented on **Figure 2-10**.

2.10.2 WETLANDS DELINEATION

Wetlands are defined in the Federal Clean Water Act (CWA) 1972 regulations (40 CFR Part 232.2(r)) as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas". The extent, type, quality / functionality, and presumed jurisdictional status of wetlands and other waters (including open water, perennial streams, and intermittent and ephemeral streams) in the Wetland Evaluation Area, within the OU3 Study Area at the Libby Site, where potential remedial activities may occur, must be accurately evaluated and characterized (refer to **Figure 2-11**) as part of the FS. Disturbance of these types of areas is regulated under the CWA because of their influence on water quality of navigable waters. The presence of these features, therefore, may alter the screening of remedial options in the FS.

Typically, Section 404 of the CWA (implemented jointly by the U.S. Army Corps of Engineers [USACE] and EPA) requires that anyone interested in depositing dredged or fill material into waters of the United States, including wetlands, must receive authorization, either through issuance of an individual permit, or pursuant to a general permit. As indicated in the EPA publication, *Considering Wetlands at CERCLA Sites* (EPA, 1994a), the Section 404 program operates independently of the CERCLA program:

> "CERCLA Section 121(e) provides that no Federal, State, or local permit shall be required for the portion of any removal or remediation action conducted entirely on-site, where such remedial action is selected and carried out in compliance with Section 121. This does not remove the requirement to meet (or waive) the substantive provisions of permitting

> regulations that are an applicable or relevant and appropriate requirement (ARAR) at the site." (EPA, 1992)

Additionally, for CERCLA sites, the EPA approaches wetland protection within the framework of the Executive Order for Protection of Wetlands (E.O. 11990), which specifies avoidance of long- and short-term adverse impacts associated with the destruction or modification of wetlands and avoidance of direct or indirect support of construction in wetlands whenever there is a practicable alternative. E.O. 11990 addresses all wetlands, and is not restricted to jurisdictional wetlands only. USACE and the EPA will coordinate to determine which agency will take the lead in reviewing and coordinating substantive permitting efforts. If wetlands are found within the Wetland Evaluation Area, impacts from potential remedial activities on these areas must be assessed in full as part of the FS process.

An internal preliminary wetlands desktop study was performed to assess the potential extent of jurisdictional wetlands within the Wetland Evaluation Area as shown on **Figure 2-11**. It is likely that many of the wetlands and permanent waterways within the OU3 Study Area Wetland Evaluation Area would be considered jurisdictional based on their connection with Rainy Creek and, ultimately, the Kootenai River. This follows from the EPA and USACE (2007) position that agencies will assert jurisdiction over "relatively permanent non-navigable tributaries of traditional navigable waters and wetlands with a continuous surface connection with such tributaries." Intermittent tributaries may or may not be considered jurisdictional. According to the EPA and USACE (2007), tributaries of traditional navigable waters that have continuous flow at least seasonally (typically three months) are considered jurisdictional. Tributaries that are not relatively permanent may also be considered jurisdictional if they "significantly affect the chemical, physical and biological integrity of downstream traditional navigable waters." Swales, erosional features, and ditches are typically not considered jurisdictional (EPA and USACE, 2007). However, in 2015, after the internal preliminary desktop review was completed, USACE and the EPA published a Clean Water Rule clarifying the scope of the definition of "waters of the United States" to include certain tributaries and "adjacent waters" (USACE and EPA, 2015). The Clean Water Rule has been stayed by judicial decision while the Rule is undergoing judicial review. EPA and the Corps are, as a formal matter, currently relying on the 2007 guidance; however, it is likely that, even if the 2015 Rule does not survive judicial review, the science underlying it will be applied by EPA and the Corps in determining what waters are jurisdictional. The appropriate methodology for evaluating jurisdictional status of water bodies will be reviewed prior to study implementation.

Information from an intensive field survey, including the USACE three parameter criteria test (i.e., vegetation, soils, hydrology) and wetland delineation, evaluation of wetland condition, delineation of stream OHWM, and stream assessment, can be used to identify and confirm the location, and condition of wetlands and other waters that may be considered jurisdictional waters and can, therefore, be addressed in a manner consistent with Section 404 of the CWA and E.O. 11990. The evaluation occurred in the spring of 2016 and included mapping and assessment of wetlands and other waters in accordance with the *SAP/QAPP Wetland Delineation, Revision 0* (MWH, 2015b). Detailed information on the 2016 Wetland Delineation field sampling effort, including all associated field documentation, will be provided by MWH in a forthcoming Wetlands Delineation Report.

During the FS process, potential impacts to jurisdictional areas and other wetlands will be calculated and, if required, possible compensatory mitigation measures will be evaluated. The USACE Omaha District Office, in collaboration with the EPA and state and local agencies, will make the final determination of whether features are jurisdictional (i.e., jurisdictional determination) or protected under E.O. 11990, and, if it is determined that impacts would occur to

protected features, whether proposed mitigation measures are required and adequate. Information that investigators gather about wetland and stream condition will be used at that time to determine appropriate mitigation levels if wetland and/or water features are impacted.

2.10.3 AQUATIC SPECIES

Two separate evaluations were conducted for aquatic species populations occurring in the OU3 Study Area as parts of the *Final Asbestos BERA* (EPA, 2014a) and the *Final Non-Asbestos BERA* (CDM Smith, 2013c). The aquatic species populations were evaluated by scrutinizing two separate areas, the Rainy Creek Watershed and the Kootenai River. These population evaluations are summarized below.

Rainy Creek Watershed. Within the Rainy Creek watershed, there are streams and ponds that provide habitat for a range of aquatic species including fish, invertebrates, and amphibians. Species identified during site-specific ecological population surveys performed as part of the OU3 Study Area RI are summarized in **Tables D-1** through **D-3** of **Appendix D**. In brief, fish surveys performed in the OU3 Study Area streams indicate that the most common species of fish are westslope cutthroat trout (*Oncorhynchus clarkii lewisi*), rainbow trout (*Oncorhynchus mykiss*), and "cutbow" trout (a rainbow/cutthroat hybrid). Brook trout (*Salvelinus fontinalis*) were not observed in the OU3 Study Area, but were observed in nearby reference streams. Aquatic invertebrate community surveys in the OU3 Study Area indicate that the most common types of aquatic invertebrates observed include mayflies, stoneflies, caddisflies, true flies, and beetle larvae. The most common amphibian species observed are the northern tree frog (*Pseudacris regilla*), Columbia spotted frog (*Rana luteiventris*), and western toad (*Bufo boreas*).

Kootenai River. No site-specific studies of aquatic species in the Kootenai River have been performed as part of the OU3 Study Area RI. However, EPA's EMAP has collected aquatic community data at a station on the Kootenai River about one mile downstream of the confluence with Rainy Creek. This location was sampled in August 2002. Forty-four species of aquatic invertebrates were observed, including oligocheates, insects (diptera, ephemeroptera, trichoptera and hemiptera), cnidaria (hydra), mollusks, and nematodes (which are listed on **Table D-4** of **Appendix D**). Eleven species of fish were observed; along with several species of salmonids (i.e., rainbow trout, sockeye salmon, cutthroat trout, and bull trout) and several species forage fish (i.e., dace, shiner, sculpin).

Water use class designations and the extent of the Rainy Creek Watershed are presented on **Figure 2-5a**.

2.10.4 TERRESTRIAL SPECIES

The forested area of the OU3 Study Area is suitable habitat for a wide range of terrestrial species, including mammals, birds, and reptiles. In order to identify wildlife species likely to occur in the OU3 Study Area, information available from the MNHP was utilized as part of the *Final Asbestos BERA* (EPA, 2014a) and the *Final Non-Asbestos BERA* (CDM Smith, 2013c). First, species known to occur within Lincoln County, Montana, were identified using the MNHP Animal Tracker webpage (http://nhp.nris.mt.gov/Tracker/). Next, the MNHP and MFWP Animal Field Guide (http://fieldguide.mt.gov/) were consulted to evaluate if a particular species was observed in the vicinity of the OU3 Study Area. Species not identified within the vicinity of the OU3 Study Area, and those not expected to occur at the OU3 Study Area based on a consideration of available habitat, were removed. The species that remained are listed in **Tables D-2**, **D-3**, **D-6**, **D-7**, and **D-8** of **Appendix D**, along with information on general habitat requirements, habitat type for

foraging and nesting, feeding guild, typical food, migration and hibernation, longevity, home range, and size. The year of the oldest, the most recent recorded sighting, and the number of individuals identified are also indicated. The species identified as residing all, or part of the year, within the OU3 Study Area include 29 invertebrates (26 terrestrial and three aquatic), seven amphibians, seven reptiles, 175 birds, and 48 mammals (refer to **Tables D-2, D-3, D-6, D-7**, and **D-8** of **Appendix D**).

2.10.5 FEDERAL AND STATE SPECIES OF SPECIAL CONCERN

As part of the *Final Asbestos BERA* (EPA, 2014a) and the *Final Non-Asbestos BERA* (CDM Smith, 2013c) the federal and state species of special concern were classified. **Table D-9** of **Appendix D** lists the animal and plant species federally protected under the Endangered Species Act and likely to occur in the Kootenai National Forest (USFWS, 2014). **Table D-10** of **Appendix D** lists species currently listed by the Montana Natural Heritage Program (MNHP) as being of concern to the state that occur in the general area of the OU3 Study Area (MNHP, 2014). Based on an evaluation of habitat requirements, the following listed species are considered the most likely to occur in the OU3 Study Area:

Federal:

- Bull Trout (*Salvelinus confluentus*)
- White Sturgeon (*Acipenser transmontanus*) (Kootenai River only)
- Grizzly Bear (*Ursus arctos horribilis*)
- Canada Lynx (*Lynx canadensis*)

State:

- Coeur d'Alene Salamander (*Plethodon idahoensis*)
- Boreal Toad, Green; also known as Western Toad (*Bufo boreas*)
- Flammulated Owl (*Otus flammeolus*)
- Northern Goshawk (*Accipiter gentilis*)
- Bull Trout (*Salvelinus confluentus*)
- Torrent Sculpin (*Cottus rhotheus*)
- Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*)
- Canada Lynx (*Lynx canadensis*)

The Kootenai River is designated critical habitat for the bull trout, and the north-central portion of the OU3 Study Area contains designated critical habitat for the Canada lynx (EPA, 2014a).

2.11 CONCEPTUAL SITE MODEL

A conceptual site model (CSM) is a schematic summary of what is known about the nature of source materials at a site, the pathways by which contaminants may migrate through the environment, and the scenarios by which receptors may be exposed to site-related contaminants. The OU3 Study Area CSMs developed by EPA are depicted graphically in the following figures:

- **Figure 2-12** depicts the CSM for human inhalation exposures to LAA and is an adaptation of the CSM developed for the *Final LAA HHRA* (EPA, 2015a). The adapted CSM is presented for human exposure to LAA specific to the OU3 Study Area and is discussed below and in **Section 7.2.2.**

- **Figure 2-13** depicts the CSM for ecological receptors to LAA.
- **Figure 2-14** depicts the CSM for human exposure to non-asbestos contaminants.
- **Figure 2-15** depicts the CSM for exposure of ecological receptors to non-asbestos contaminants.

The following sections provide a summary of the main elements of the CSM.

2.11.1 Sources of LAA and Non-Asbestos Containing Materials

This section includes a discussion of known and potential sources of LAA and non-asbestos containing material related to one of the following:

- naturally occurring materials and processes,
- mine site and past mining, milling, processing, and disposal activities within the OU3 Study Area, and
- processing, transportation, and disposal activities originating outside of the OU3 Study Area.

2.11.1.1 Sources from Naturally Occurring Materials and Processes

An extensive background study has not been conducted at the OU3 Study Area to evaluate the degree to which natural occurrences of LAA and non-asbestos constituents may contribute to observations of those constituents in the OU3 Study Area. However, for completeness, a brief description of naturally occurring potential sources is provided.

LAA. The following are considered potential sources of LAA that are naturally occurring, and considered to be present regardless of the historical mining operations.

- The ore body in Vermiculite Mountain is expressed as a roughly circular outcrop rimmed with Precambrian Belt Formation meta-sedimentary rocks. The formation of vermiculite and asbestiform amphiboles in the Libby mine ore body is believed to be the result of the hydrothermal alteration of augite by high-temperature silica-rich solutions (Pardee *et al.*, 1929; Boettcher, 1967; Van Gosen *et al.,* 2002; Meeker *et al.,* 2003). The primary source of LAA within the Former Mine Area is the zone of vermiculite pyroxenite, the ore body. The asbestos structures originating from the Vermiculite Mountain ore body contain detectable levels of both sodium and potassium, whereas other potential sources of LAA may not (CDM Smith, 2014b). These detectable levels of sodium and potassium are a signature of the LAA originating from the ore body. Naturally occurring wind and water erosion of areas of unmined exposed bedrock containing potassium and sodium signature amphiboles is considered a potential source of LAA.
- Glacial deposits at the Former Mine Area and Libby Site contain amphibole asbestos eroded from Vermiculite Mountain during Pleistocene glaciation. In addition, surface water flows of the creeks within the OU3 Study Area are actively down-cutting into the glacial deposits. As such, the natural water erosion of the glacial deposits is considered a potential source of LAA to the creeks.

Non-asbestos Constituents. Natural weathering, both mechanical and chemical, of the vermiculite ore body will generate soils that will reflect the chemical composition of the parent

rock. Therefore, a reasonable expectation is that the elements associated with primary- and secondary-mineral phases contained in the RCC (refer to **Section 2.6.2**) will also be concentrated in the weathering profile of soils and sediments derived from the bedrock and potentially in water that contacts the soils, sediments, and rock. Primary minerals are formed during the original crystallization of the parent rock and secondary minerals are formed by the weathering of primary minerals. Based on review of the mineralogy of the RCC described in Weeks (1981) and Frank and Edmond (2001), the following list provides potential mineral sources for elements that have the possibility of naturally occurring elevated concentrations in the OU3 Study Area:

Element	Potential Mineral Source
Aluminum	Aluminosilicate minerals
Arsenic	Pyrite
Barium	Barite
Beryllium	Quartz, biotite
Chromium	Chromite, pyrite, biotite
Cobalt	Pyrite, biotite
Copper	Pyrite, copper sulfide, biotite
Fluoride	Fluorapatite, biotite
Iron	All minerals
Lead	Pyrite
Manganese	Biotite, pyrite, Mn-oxide
Nickel	Ni sulfide, biotite, pyrite
Phosphorus, Total	Fluorapatite
Thallium	Pyrite, biotite
Vanadium	Pyroxene minerals

It should be noted that the descriptions available of the mineralogy associated with the ore body and surrounding geology at the Former Mine Area, pyrite is the most likely primary mineral phase that could contain arsenic as a trace constituent. While pyrite occurs in the ore body, the abundance is generally low. In the context of acid base accounting, as an overall descriptor of geochemical properties of the rock, there is an abundance of neutralizing mineral phases as compared to acid producing minerals. This means that while pyrite exposed to atmospheric conditions will oxidize and release iron, sulfate, and trace elements (such as arsenic), the preponderance of neutralizing minerals will maintain pH such that the iron will precipitate as iron oxyhydroxides and will probably sorb arsenic, significantly limiting the mobility of arsenic.

2.11.1.2 Sources from Past Mining, Milling, Processing, and Disposal Activities

Sources of LAA and non-asbestos constituents associated with the former mine site and past mining, milling, processing, and disposal activities within the OU3 Study Area are discussed herein. Former Mine Area features are presented on **Figure 1-3**.

As discussed in **Section 1.3**, there is a long history of mine-related activities within the OU3 Study Area. These activities were a likely source of LAA and potential non-asbestos constituents in the OU3 Study Area.

The potential sources of LAA and non-asbestos constituents at the mine site, and resulting from mining activities are summarized below by material, location, or activity.

Mine Benches. Exposed rock on the mine benches remains at the upper elevations of the Former Mine Area and consists mainly of vermiculite ore that remains unmined. The vermiculite ore

contains veins of LAA of varying thickness. These exposed veins are subjected to weathering, which could result in releases of LAA in the Former Mine Area. In addition, weathering of bedrock could also release the non-asbestos constituents.

Waste Rock. During mining efforts, the rock overlying and adjacent to the ore body was removed. This rock was hauled in trucks and deposited off the south flank of the dome-shaped pluton. The waste rock piles are made up of a mixed mass of the different overburden rock types (i.e., syenite, unaltered biotite, quartz, and other non-vermiculite materials). The slopes of the waste rock piles vary between 10 degrees to 40 degrees. The largest of the waste rock piles dammed Carney Creek on the southwest portion of the property and created Carney Pond. Erosion of waste rock is a potential source of both LAA and non-asbestos constituents.

Mine Roads. Mined materials have been used to construct roads within and around the active mining areas of the Former Mine Area (EPA, 2007c). Road fill materials are a potential source of both LAA and non-asbestos constituents. In addition, past use of the application of oil on mine roads as a dust control measure was reported (EPA, 2007b).

Coarse Tailings. The coarse tailings are located in the northwestern and western portions of the Former Mine Area (refer to **Figure 1-3**). Coarse non-vermiculite materials, typically sand-size and larger, were screened out at the mill located on the mine property and were deposited on the coarse tailings pile on the north flank of the mine. Prior to full conversion to the wet-mill process in 1974, coarse tailings were hauled and deposited by truck. Coarse tailings are a potential source of both LAA and non-asbestos constituents.

Tailings Impoundment. The tailings impoundment was constructed to contain fine tailings from the Former Mine Area. Fine tailings are generally sand-size and finer particles that passed through screens at the former mill located on the mine property (refer to **Figure 1-3**). The tailings were processed through thickeners and deposited as slurry to the fine tailings impoundment. Before construction of the KDID, fine tailings were deposited directly into Rainy Creek. The thickness of the fine tailings in the tailings impoundment varies between approximately 30 ft. and 90 ft. Under most conditions, the tailings impoundment drains through a system of embankment underdrains and toe drains directly into LRC, but may also discharge to LRC via an overflow channel during high flow events (Parker and Hudson, 1992). The tailings impoundment is a potential source of both LAA and non-asbestos constituents.

Amphitheater Area and Other Vermiculite Materials. The results of a field investigation conducted in October 2011 indicated that Rainy Creek flowed through an area containing vermiculite waste (VW) located below the area referred to as the Amphitheater, which is located to the southwest of the Mill Pond. The VW area was a potential source of LAA to LRC prior to removal efforts. Removal efforts to mitigate the potential source were implemented in the fall of 2012 and summer of 2013, during which more than 15,500 cubic yards of VW was removed. This removal effort is described in further detail in **Section 4.5.2**. In addition, vermiculite materials were also observed in discrete piles, embankment fills, and general fill materials, may have been collocated with LAA-bearing materials (MWH, 2015). All of these materials are potential sources of both LAA and non-asbestos constituents.

Transportation. The movement and transportation of materials containing LAA from mining activities is considered a potential source to areas and surface waters near and adjacent to transport routes. Prior to the construction of an on-site mill in 1936, ore was transported by skip and trucked to Libby by Montana Highway 37 for processing at facilities in the town of Libby (Boettcher, 1963), where transportation may have resulted in LAA releases to areas along the

route (e.g., Rainy Creek, Kootenai River). The original on-site dry mill was constructed in 1936 east of the mined area (refer to **Figure 1-3**), and based on available documents, processed vermiculite material was transported from the mill site down the northwest facing hill slope along a tramway to a loading area positioned on the south hill slope above Rainy Creek. The material was then transferred from the loading area into haul trucks for delivery off-site.

Vermiculite Processing. The vermiculite processing within the Former Mine Area included both dry and wet mill milling conducted at the site as described in **Section 1.3**. The mill operations conducted in the Former Mill Area (refer to **Figure 1-3**) was the primary source of aerial deposition of LAA. Air dispersion modeling was conducted using the EPA's American Meteorological Society/EPA Regulatory Model (AERMOD) modeling system to estimate the footprint of aerial deposition of LAA resulting from former mining operations in the OU3 Study Area. The results of the modeling and analysis are presented in *Libby Operable Unit 3: Dispersion Modeling and Analysis* (Reax Engineering, 2015) and discussed in **Section 5.0**. In addition, some chemicals used at the mine site in the processing of vermiculite ore might also be present in waste materials on the Former Mine Area. Various reagents were used to facilitate the separation of higher quality ores from lesser quality ores. The reagents reported included #2 diesel fuel, Armeen T (tallow alkyl amine), fluorosilicic acid, and lesser quantities of flocculants, defoamers, frothers, and other reagents.

Land Disturbance. Surface water run-off from the Former Mine Area and other areas of the OU3 Study Area impacted by releases from historical mining activities has the potential to mobilize LAA and non-asbestos constituents and is thus a potential source. Water that contacts exposed hillsides, waste rock piles, and mine tailings has the potential to mobilize (by eroding or leaching) non-asbestos constituents such as metals and metalloids. As a result, these metals/metalloids can become concentrated in depositional areas (e.g., in sediments), or dissolved or suspended in surface water or groundwater at concentrations that are toxic or otherwise detrimental to the environment. Weathering of exposed rock that contains an abundance of sulfide materials (such as pyrite) can result in acidic (low pH) discharges. As discussed in **Section 2.9**, minor pyrite is present in the principal bedrock geology, as expressed at the surface, and may react with groundwater and surface water. However, the Stiff diagrams shown on **Figures 2-8** and **2-9** show the water is dominated by calcium bicarbonate, which would have a neutralizing effect on water pH, and there is limited to no sulfate present in the water indicating that low pH drainage is not impacting surface and groundwater at the site.

As discussed above, erosion of the source rock, waste rock piles, tailings, and stockpiled materials has likely caused transport of LAA-bearing materials and deposition of sediment in surface water bodies near the Former Mine Area. However, as discussed in (MWH, 2016a), it is apparent that migration of sediments in creeks within the Former Mine Area largely occurs during higher flow events. In order for sediments impacted by releases from mining activities to flow from the Former Mine Area to the Kootenai River, the material would have to be transported during periodic high flow events approximately 2.5 miles down LRC. Transport of LAA-bearing materials would also likely have been further hampered by the presence of low energy pools and possible wetland areas along LRC.

Landfarming. Landfarming activities conducted within the Former Mine Area are considered a potential source of non-asbestos constituents. As part of the mine closure, the underground diesel storage tanks at the Former Mine Site were removed in 1991 (MWH, 2013a). During removal, sampling of soil within the vicinity of Tanks 1, 2, 3, 4 and 9 indicated elevated levels of total petroleum hydrocarbons (TPH). With permission from the Montana Department of Health and Environmental Sciences, now MDEQ, Grace excavated and landfarmed up to 800 cubic yards

(cy) on a concrete foundation pad (200 x 300 ft.) on Vermiculite Mountain. Soil sampling conducted in 2013 at the landfarm indicated the presence of petroleum hydrocarbons, although when ranges were compared against their respective Montana Tier 1 Risk Based Screening Levels for Petroleum Releases (MDEQ, 2009), only C11-C22 aromatics slightly exceeded its screening level of 400 mg/kg at a concentration of 424 mg/kg (MWH, 2013a). Sampling information is presented in **Section 4.5.3** and the location of the landfarm is shown in **Figure 2-16**.

Historical Landfill. A minor landslide in the waste rock pile to the southwest of the former mill exposed a historical landfill, which was identified during the initial reclamation efforts in the mid-1990s (**Figure 2-16**). This landfill is considered a former source location. Based on the available records, the landfill contained primarily construction debris from the demolition of the mill (W.R. Grace, 1986). Cleanup efforts of the landfill occurred in 1995 and 1996.

2.11.1.3 Sources Originating Outside of the OU3 Study Area

Several potential sources of LAA have originated outside of the OU3 Study Area and it should be noted that it is not possible to distinguish between LAA associated with the Former Mine and LAA associated with other OUs. These other potential sources include remediation soils brought from OU1, OU2, OU4, and OU7 into the OU3 Study Area (refer to **Figure 2-17**), possible wind-dispersed dust from OU2, and possible source areas (OU1, OU2, and OU4) contributing to the presence of LAA within the Kootenai River (e.g., government application of LAA-containing riprap along the Kootenai River, historical spills of vermiculite ore and/or concentrate from areas now designated as part of other OUs such as OU2 and OU4).

Since 2000, approximately 1.1 million cubic yards of LAA-contaminated soils have been brought into the OU3 Study Area as part of Libby Site remedial efforts in OUs 1, 2, 4, and 7 (Cirian, 2016), such as soils removed from residences in the town of Libby that are designated as OU4. These soils were stockpiled in the Former Mine Area in the location shown on **Figure 2-17,** and the majority was beneficially re-used to reclaim and revegetate areas disturbed by mining activities in the OU3 Study Area. However, not all of the soils could be used for beneficial purposes because some of the soil transported during the beginning of the program was intermixed with PPE and other cleanup debris. These soils were placed in a separate area at the top of the mine.

The former Screening Plant (OU2), which was located adjacent to the mouth of LRC and the East side of the Kootenai River, was used initially for transfer of materials and ultimately for screening of vermiculite beginning in the 1950s. Given the prevailing wind direction is toward the northeast in the area, the facility was likely a contributor to airborne dust that may have been released to the southern portion of the OU3 Study Area. Estimated asbestos emission rates for the former Screening Plant were 0.0149 pounds per hour (lb/hr), which is more than 200 times lower than the emission rates for the dry mill, which were estimated to range from 4.08 to 20.48 lb/hr (CDM Smith, 2015a).

There are numerous potential sources of LAA to the Kootenai River from areas outside of the OU3 Study Area. Although it is not possible to quantify the portion or percentage of LAA contribution to the Kootenai River from each of these sources, considering the LAA source material quantities handled in these areas throughout the years of operation, it is reasonable to assume that the amount of LAA material from these areas that entered the Kootenai River may not be inconsequential. Each of these areas, including a brief summary of the investigations, sampling results, and removal actions, are summarized below.

OU1 – Former Export Plant. LAA-bearing materials were managed for at least 30 years on the former Export Plant (OU1) property, which covered roughly 17 acres and was located immediately adjacent to the south side of the Kootenai River in the city of Libby. Mine records indicate that over 350,000 tons of vermiculite concentrate were managed at the former Export Plant in the four-year period between 1945 to 1949 (i.e., approximately 13% of the time during which vermiculite concentrate was handled at this location).

As described in the OU1 RI Report (CDM Smith, 2009a), between 1999 and 2006 numerous sampling investigations occurred within OU1 to characterize the extent of LAA material. During visual inspections, vermiculite was observed throughout OU1, including in numerous areas along the entire length of the riverbank. Soil sampling detected concentrations of LAA from ND to ≥1% in surface and subsurface soil samples obtained within OU1. These data prompted EPA to execute a number of soil removal actions within OU1 along the bank of the Kootenai River and in the area where the Export Plant was located. Although not addressed in the OU1 RI Report (CDM Smith, 2009a), historical operations and activities within OU1 (stockpiling, staging, distributing vermiculite and vermiculite concentrate, and moving materials around for fill, etc.) are likely to have contributed to LAA impacts to the Kootenai River via vermiculite concentrate washing/blowing directly into the Kootenai River.

OU2 – Former Screening Plant and Surrounding Properties. The former Screening Plant (OU2), which was approximately 21 acres in size and located on the east side of the Kootenai River, was where LAA concentrate was size-sorted and transported by a conveyor bridge system across the river to the rail load-out system on the other side of the river adjacent to the Burlington Northern Rail Lines (CDM Smith, 2009b). Mine records indicate that in the period between 1975 and 1990 over 6,600,000 tons of vermiculite concentrate were managed in the former Screening Plant area. In addition, in 1979, two freight cars derailed at the former Screening Plant and crushed the rail loading facility which caused the conveyor bridge (used to transport vermiculite material across the Kootenai River) to collapse into the Kootenai River (Missoulian, 1979; Western News, 1979). Because the conveyor belt was covered by a roof but open on the sides, the vermiculite material on the conveyor belt at the time of collapse would have spilled into the Kootenai River (refer to **Figure 2-18**). In addition to the conveyor collapse, spillage from the open sided conveyor system into the Kootenai River was likely during normal operations (i.e., excessive material on the conveyor falling into the river through the open sides, and wind blowing the material from the conveyor belt into the river).

As described in the OU2 RI Report (CDM Smith, 2009b), between 1999 and 2006 numerous sampling investigations occurred within OU2 to characterize the extent of LAA material. Vermiculite was observed throughout OU2 including in areas along the riverbank. Soil sampling detected concentrations of LAA from ND to ≥1% in surface and subsurface soil samples. These data prompted EPA to execute a number of soil removal actions within OU2. Although not addressed in the OU2 RI Report (CDM Smith, 2009b), historical operations within OU2 (stockpiling, staging, conveying materials on a conveyor across the Kootenai, etc.) and the conveyer bridge collapse are likely to have contributed to LAA impacts to the Kootenai River via vermiculite concentrate washing/blowing/being dumped directly into the Kootenai River.

OU4 – Residential, Commercial, Industrial and Public Properties: Based on investigations and evaluations conducted as part of the OU4 RI, some of the properties adjacent to the Kootenai River required response actions due to LAA impacts which are detailed in the OU4 RI Report (CDM Smith, 2014a). The Kootenai Bluffs Subdivision (referred to herein as the Bluffs) is one such area which is located on the west side of the Kootenai River along the riverbank, directly across the river from the former Screening Plant (OU2). The conveyer bridge system ran between

the Screening Plant and the Bluffs. The Bluffs served as a conveyor unloading station where vermiculite concentrate was loaded onto trucks or railroad cars for distribution. Based on the results of visual inspections and surface and subsurface soil sampling (CDM Smith, 2014a), the EPA initiated a removal action in this area. Although not addressed in the OU4 RI Report (CDM Smith, 2014a), it is reasonable to assume that some LAA material from the Bluffs area, likely through airborne dust, may have contributed LAA material to the Kootenai River.

Additionally, four creeks, all tributaries of the Kootenai River, required removal actions due to placement of LAA-impacted riprap. These removal actions were performed by the United States Army Corps of Engineers (USACE), Lincoln County, the City of Libby, and/or private landowners to control erosion. Removal actions in response to the investigation findings in Flower Creek, Granite Creek, Pipe Creek, and Libby Creek were completed under the Emergency and Rapid Response Services Contract, and included the removal of LAA-contaminated soil and riprap material from along the creek embankments as directed in the addendums to the Response Action Work Plan for the creeks (CDM Smith, 2008a,b; CDM Smith, 2009c,d). A total of 2,600 cubic yards of contaminated soil and riprap material was removed from Flower Creek; 3,370 cubic yards of contaminated soil and riprap material was removed from Granite Creek; 357 cubic yards of contaminated soil and 20 truckloads of contaminated riprap material were removed from Pipe Creek; and 499 cubic yards of contaminated soil and 95 truckloads of contaminated riprap material were removed from Libby Creek. Although not addressed in the OU4 RI Report (CDM Smith, 2014a), it is reasonable to assume that LAA-contaminated soil and riprap material from along the creek embankments, some of which was noted as containing 100% asbestos, from these tributaries within OU4 likely contributed LAA material to the Kootenai River (EPA, 2008a).

2.11.2 Possible Migration Pathways

Air Transport. It is possible that constituents in dust, ash, soil, or mine waste may become suspended in air and transported from source areas via physical disturbance (e.g., wind, fire, human disturbance). Once airborne, contaminants may move with the air and then settle and become deposited onto the surface of vegetation, soils, and/or structures downwind. However, evidence shows that fibers tend to stay in the media rather than travel in the air in the absence of physical disturbance (Ward *et al.*, 2009; EPA, 2012i).

Surface Transport. Constituents may be carried in surface water runoff (e.g., from rain or snowmelt) from the mine, or other areas where dust, ash, soil, rock, or mine waste contains LAA and become deposited in soils or sediments at downstream locations.

Transport by Humans. Humans could transport materials impacted by releases from mining activities during collection of firewood and other materials at the OU3 Study Area.

2.11.3 Receptors and Populations of Concern

A range of different human receptors could potentially be exposed to contaminants in the OU3 Study Area, including:

- **Trespasser in the Former Mine Area** – This population includes older children and adults who trespass on the area of the OU3 Study Area that has been disturbed by past mining activities. The types of activities performed may include hiking, hunting, and all-terrain vehicle (ATV) riding within the Former Mine Area.

- **Recreational visitors along streams and ponds** – This receptor population includes adults and older children who hike, fish, wade/swim or explore streams and ponds in portions of the OU3 Study Area outside the Former Mine Area.
- **Recreational visitors in the forested area** – This receptor population includes older children and adults who engage in activities in the forested area in the OU3 Study Area outside the Former Mine Area, such as camping, hiking, dirt bike riding, ATV riding, hunting, etc.
- **Wood cutters in the forested area** – This receptor population includes adult area residents who engage in sawing, hauling, and stacking wood for personal use, as well as adult workers who are employed in commercial logging operations in the OU3 Study Area. This scenario would also include potential exposures to woodstove ash generated from firewood collected from the OU3 Study Area.
- **USFS workers and firefighters in the forested area** - This receptor population includes adult workers who engage in routine USFS activities (e.g., tree stand examination, thinning vegetation, and trail maintenance) and firefighters who may respond to forest fires in the forested area of the OU3 Study Area.

Residential receptors are not included as potential receptors in the OU3 Study Area. This is because any properties geographically within OU3 (primarily located along the southern border of the OU3 Study Area) that are currently residential have been evaluated as part of OU4.

Ecological receptors can be grouped as follows:

- Aquatic receptors (fish, benthic invertebrates, aquatic plants, and amphibians)
- Terrestrial plants and soil invertebrates
- Birds and mammals
- Reptiles

2.11.4 Exposure Pathways of Concern

The exposure pathways of concern for LAA are depicted on **Figures 2-12** and **2-13**. Of the exposure routes, inhalation exposure of LAA to terrestrial receptors is considered to be of greatest concern. To the extent that ingestion contact exposures may occur at the site (e.g., ingestion of LAA in drinking water or food), the added risk to human health from ingestion is expected to be negligible compared to the risk from inhalation (EPA, 2015a).

The exposure pathways of concern for non-asbestos constituents are depicted on **Figures 2-14** and **2-15**, and include ingestion, inhalation, and direct (dermal) contact.

3 DATA COLLECTION AND MANAGEMENT

3.1 INTRODUCTION

Multiple RI sampling phases/events have occurred in the OU3 Study Area from 2007 to 2015, and additional events are planned. This section presents the:

- sampling overview for both LAA and non-asbestos samples,
- database used for compilation and reporting of the OU3 Study Area sample data,
- data that have been excluded from this RI report,
- analyses that were run on the collected media samples, and
- QA/QC measures that were undertaken in the field and in the laboratory to provide useable data.

A discussion of analyses performed, grouped chronologically and by sample media type, is presented in **Section 4.0**. A discussion of analytical results is presented in **Section 5.0.**

3.2 SAMPLING OVERVIEW

Over the eight-year period of RI activity phases/events in the OU3 Study Area completed to date, more than 2,200 field samples have been collected and analyzed for asbestos and more than 300 field samples have been collected and analyzed for non-asbestos constituents for different media or receptor types including:

- surface water,
- groundwater,
- sediment,
- soil and mine waste from the Former Mine Area,
- forest soil, duff material, ash, and tree bark from forested areas,
- air (outdoor ambient/perimeter air and ABS air samples), and
- fish and mammal tissue analysis.

In addition, several ecological community evaluations (fish, benthic invertebrates, amphibians, and small mammals) and site-specific toxicity tests have been conducted. Sample totals per media are presented on **Table 4-1**. Samples of surface water, groundwater, sediment, soil, mine waste, and forest soil were collected during one or more RI events for analysis of both LAA and non-asbestos constituents. Samples collected from tree bark and duff material from forested areas, ash, outdoor ambient/perimeter air, and activity-based air samples (ABS) were analyzed for LAA only. Further detail on sample phases/events design and collection details are presented in **Section 4.0.** Samples results (i.e., the nature and extent) are discussed in detail in **Section 5.0** by media type and analytical result (LAA or non-asbestos).

3.3 OU3 STUDY AREA DATABASE

Application. The master OU3 Study Area project database is a Microsoft Access® relational database that has been developed specifically for the OU3 Study Area. Due to the management of the Libby Superfund Site, the nature of LAA analysis and other data reporting requirements, the database has been developed iteratively, expanding in its capabilities (and complexity) as

project-specific needs have evolved. In addition to providing new functionality, as needed, enhancements have been made to accommodate user needs and to incorporate various automated QA/QC procedures to improve data integrity.

Because data continues to be generated as a result of ongoing sampling and analysis in the OU3 Study Area, the project database is dynamic. New sample analysis and results records are added and records are corrected, as appropriate. As a result, any database-generated queries, tables, figures, maps, and reports provide only a "snapshot" of the database on the day the output was created. **Appendix B-2** provides a snapshot of the project database as of November 30, 2016. This snapshot was used to prepare the data summaries included in this report. **Appendix E** provides detailed data summary tables created from the OU3 Study Area project database snapshot.

Administration and Security. EPA's contractor, CDM Smith, controls day-to-day operation of the OU3 Study Area project database, including physical and network security, access rights, and data backup. The OU3 Study Area project database is kept on the CDM Smith server in Denver, Colorado. Incremental backups of the CDM Smith server are performed daily Monday through Friday, and a full backup is performed each Saturday. Access to the server is restricted to approved-CDM Smith personnel only.

Data Entry Processes. The OU3 Study Area project database has a variety of built-in QC functions that improve accuracy of data entry and help maintain data integrity. For example, field data entry forms utilize drop-down menus whenever possible. Drop-down menus allow the data-entry personnel to select from a set of standard inputs. The use of drop-down menus prevents duplication and transcription errors and limits the number of available selections (e.g., valid media types). In addition, the project data allows a unique sample identification number (ID) to only be entered once, thus ensuring that duplicate records cannot be created.

The analytical laboratories are required to transmit results using Libby-specific electronic data deliverable (EDD) spreadsheets. Each EDD contains a variety of built-in QC functions that improve the accuracy of data entry and help maintain data integrity. For example, data entry forms utilize drop-down menus whenever possible to standardize data inputs and prevent transcription errors. In addition, many data input cells are coded to highlight omissions, apparent inconsistencies, or unexpected values so that data entry personnel can check and correct any errors before submittal of the EDD. These spreadsheets also perform automatic computations of analytical sensitivity, dilution factors, and concentration, to help reduce analyst calculation errors.

The transmitted EDDs are uploaded directly into the OU3 Study Area project database using upload queries in Microsoft Access® designed specifically for each type of EDD, which avoids potential errors related to manual entry of the results. Each upload query performs several integrity checks to confirm that records are consistent and complete prior to uploading the analytical data. If issues are identified, the analytical EDD will not be uploaded until they are rectified.

Additionally, there are two data sets that were included as part of this report (OU4 Nature and Extent Study [EPA, 2013b] and Nature and Extent Forest Study [EPA, 2015f]) that do not reside in the Libby OU3 Study Area project database but instead reside in the Scribe database. The Scribe database maintains all OU4 sample data collected from 1999 to present, and analytical data collected since January 2010 (CDM Smith, 2014a). Scribe is a software tool developed by the EPA Environmental Response Team to assist in the process of managing environmental data.

3.4 EXCLUDED DATASETS

In some cases, results in the database have been deemed rejected as a result of validation performed by CB&I Federal Services, LLC (CB&I), EPA's Quality Assurance Technical Support (QATS) contractor, using the Libby Site specific standard operating procedures (SOPs) for data validation. These samples have been excluded from the data summaries in this report. A detailed list of the rejected samples is included in **Appendix E.** Data validation SOPs referenced in this report are provided in **Appendix F**.

Additionally, data collected prior to 2007 will not be utilized in evaluations moving forward in this report because the data collection objectives differed from the data collected post 2007. The post 2007 data were collected under one of the QAPP's developed as part of the OU3 Study Area RI per the AOC, whereas the pre 2007 data were collected to support emergency response efforts. Pre 2007 data are provided in **Appendix A.**

3.5 ANALYTICAL METHODS

Samples of surface water, groundwater, sediment, soil, mine waste, and soil were collected during one or more RI events for analysis of both LAA and non-asbestos constituents. Samples of tree bark and duff material from forested areas, ash, outdoor ambient/perimeter air, and activity-based air samples were analyzed for LAA only. The LAA and non-asbestos analytical methods are discussed below.

3.5.1 Asbestos Analytical Methods

The EPA has employed modifications to commercial asbestos test methods for various sample media collected in the OU3 Study Area, as discussed in this section. When necessary, the analytical methods were incorporated into project-specific SOPs. The analytical methods shown on **Table 3-1** were used to analyze the OU3 Study Area LAA samples and are discussed below:

PLM. The PLM method capitalizes on the fact that light passing through a translucent mineral will interact with the internal crystal structure of the mineral grains, and the transmitted light (that which passes through the particle) tends to be polarized, having a higher intensity in some orientations than in others. Because this effect depends on the composition and/or structure of the particle, each mineral has a unique effect on light passing through it. Thus, based on the optical properties of the particle (e.g., refractive index, birefringence, color), it is possible to identify the mineral. The determination of asbestos or non-asbestos is based both on the extinction angle (for monoclinic amphiboles) and on the particle morphology.

PLM is not applicable to samples that may contain many fine fibers below the resolution of the light microscope (e.g., air samples). For this reason, PLM is only applied to bulk samples of soil where many of the asbestos structures present can be expected to be fairly large.

At the Libby Site, there are two different PLM methods that are utilized to analyze soil and other bulk materials, NIOSH Method 9002 and the Libby-specific PLM methods. Only the Libby-specific PLM methods were utilized to analyze soil samples from the OU3 Study Area, as described below.

Libby-Specific PLM (including PLM visual area estimation [VE] and PLM gravimetric [Grav]). In early 2002, at the onset of the OU4 RI contaminant screening study (CSS), the EPA

determined that existing soil analytical methods, such as NIOSH Method 9002, were inadequate for measuring concentrations of LAA below 1%. Based on early ABS studies, the EPA determined that asbestos concentrations of potential health concern may be released to air from soils with low-levels (<1%) of asbestos contamination. For these reasons, the EPA has researched, developed, and evaluated other methods for the characterization of relatively low levels of asbestos in soil. EPA was also concerned about the cost and turnaround time of other methods, given the need to screen the thousands of soil samples planned to be collected under the CSS.

To address these issues, EPA, with assistance from the USGS and SRC, designed and implemented a soil performance evaluation (PE) study. The objectives of the PE study were to:

- Develop PE test materials of known, verified LAA concentrations in soil that could be used to test the efficacy of soil analytical methods.
- Use the PE test materials to evaluate multiple commercially available analytical methods and technologies to determine their suitability for detecting and measuring LAA in soil at various concentrations and under conditions similar to those found at the Libby Site.
- Based upon these results, develop and refine project-specific test methods to detect low concentrations of LAA in soil.
- Based upon the results, develop a set of acceptance criteria for the PE test materials.
- Use PE test materials as a QC tool for testing the performance of analytical laboratories.

The PE study was conducted in several test phases, with the majority of the work conducted in 2002. The details of the phased approach are described in the *Quality Assurance Project Plan, Performance Evaluation Study for Analytical Methods in Soil, Part B, Revision 1* (EPA, 2003). Soil samples for analysis by the Libby-specific PLM methods are first processed in accordance with SOP ISSI-LIBBY-01[3]. In brief, each soil sample is dried and sieved through a ¼-inch screen. Particles retained on the screen (if any) are referred to as the "coarse" fraction. Particles passing through the screen are referred to as the "fine" fraction, and this fraction is ground by passing it through a plate grinder. The resulting material is referred to as the "fine-ground" fraction. The fine- ground fraction is split into four equal aliquots; one aliquot is submitted for analysis and the remaining three aliquots are archived.

The coarse fractions are examined in accordance with SOP SRC-LIBBY-01, referred to as "PLM-Grav". SOP SRC-LIBBY-01, *Qualitative Estimation of Asbestos in Coarse Soil by Visual Examination Using Stereomicroscopy and Polarized Light Microscopy (PLM)*, was developed in 2002 and contains elements from NIOSH Method 9002 and EPA 600/R-93/116. PLM-Grav is used as a screening tool to examine the coarse soil fraction for evidence of asbestos mineral content using stereomicroscopy with confirmation of asbestos by PLM. The method is used on soil and other soil-like media (e.g., sediment) to quantify the types of asbestos fibers, including amphiboles (like those characteristic of the Libby Site) and chrysotile. The method sensitivity can be affected by the homogeneity of the sample, the accuracy of the weight measurements obtained at the laboratory, and the effectiveness of the sample reduction and filtering procedures.

[3] This soil preparation SOP was superseded by SOP 16-ASB-06.00 on July 2, 2014. The current revision of this soil preparation procedure is SOP 6-ASB-06.02.

The fine ground aliquots are examined using visual area estimation in accordance with SOP SRC-LIBBY-03, referred to as "PLM-VE". SRC-LIBBY-03, *Analysis of Asbestos Fibers in Soil by PLM*, was developed in 2003 and is based on NIOSH Method 9002, EPA 600/R-93/116, and California Air Resources Board (CARB) Method 435. PLM-VE is a semi-quantitative method that utilizes LAA-specific reference materials to allow assignment of fine-ground samples into one of four reporting "bins" as follows:

- Bin A (ND): non-detect
- Bin B1 (Trace): detected at levels lower than the 0.2% (by mass) LAA reference material
- Bin B2 (<1%): detected at levels lower than the 1% (by mass) LAA reference material but ≥0.2% LAA reference material
- Bin C: LAA detected at levels ≥1% LAA reference material; results are reported to the nearest whole percent

The details of the PE study are summarized in a separate PE study report titled: *Performance Evaluation of Laboratory Methods for the Analysis of Asbestos in Soil at the Libby, Montana Superfund Site* (EPA, 2008b).

TEM. The TEM methods are more complex than PLM and require the use of a more sophisticated analytical instrument that may operate at higher magnification (i.e., 20,000x) and hence, may detect structures much smaller than can be been seen by other methods. TEM methods can be used for air, dust, water, and solid media (e.g., soil, duff, tree bark, tissue).

When a sample is analyzed by TEM, the analyst records the size (length, width) and structure type (e.g., fiber, bundle) of each individual asbestos structure that is observed. This structure attribute information can be used to determine the number of total and phase contrast microscopy-equivalent (PCME) structures observed in the TEM analysis. Total LAA includes all structures with a length ≥0.5 µm and an aspect ratio (length:width) of ≥3:1. PCME is important for the purposes of HHRA because available toxicity values are based on studies utilizing phase contrast microscopy (PCM) data. In the PCM method (NIOSH Method 7400; NIOSH, 1994), a structure is counted as a PCM fiber if it has a length of 5 µm or longer and an aspect ratio of at least 3:1. Although there is no thickness rule specified in the PCM method, particles thinner than 0.25 µm are not usually detectable by PCM. For the Libby Site, the TEM counting rules for PCME structures are: length >5 µm, width ≥0.25 µm, aspect ratio ≥3:1. Note that the PCME counting rule for width does not include an upper width cut-off of three µm, per EPA (2008b), because particles wider than three µm are counted by the PCM method (NIOSH, 1994). Thus, to ensure comparability between the exposure concentrations and the toxicity values, no upper width restriction is applied.

The TEM analyst also records the mineral type of each individual asbestos structure that is observed. Mineral type is determined by energy dispersive spectrometry (EDS) and SAED:

- EDS is a method that takes advantage of the fact that an atom that is excited by absorbing a high energy electron will tend to re-emit the absorbed energy at a wavelength that is characteristic of the absorbing atom. Thus, when a particle is examined under a TEM equipped with EDS, it is possible to obtain data on the atomic composition of each particle being examined. This allows the examiner to distinguish organic particles from mineral particles, and also allows the examiner to distinguish between different types of mineral particles.

- SAED is a method based on the fact that crystalline structures diffract electrons to form a diffraction pattern that is characteristic of the underlying crystal structure. Thus, when a particle is examined under a TEM equipped with SAED, it is possible to obtain a diffraction pattern that can be used to confirm the mineral type (e.g., tremolite, actinolite, chrysotile) and may be useful in classifying the nature of the mineral (e.g., asbestiform, non-asbestiform).

There are many different standard methods that have been developed for TEM. These methods differ mainly in the recording rules that are utilized by the TEM analyst in reporting observed asbestos structures. At the Libby Site, the most commonly used recording rules are those specified by Asbestos Hazard and Emergency Response Act (AHERA), American Society for Testing and Materials (ASTM) International D-5755, Internal Organization for Standardization (ISO) 10312:1995(E), and EPA 100.2. However, for the OU3 Study Area samples, these common industry analytical methods have been modified. For a discussion on the recording rules, refer to Section 2.0 of the *Libby Asbestos Superfund Site Residential and Commercial Properties Operable Unit 4, Libby, Montana, Remedial Investigation Report* (CDM Smith, 2014a). Some samples have been analyzed multiple times by TEM. In these cases, the TEM results have been pooled in accordance with *Technical Memo 11* (EPA, 2007c).

The two recording rules used for samples collected from the OU3 Study Area are ISO 10312:1995(E) and EPA Method 100.2. Each method is discussed in more detail below.

TEM ISO. The ISO 10312:1995(E) method, *Ambient air – Determination of Asbestos fibers – Direct-transfer Transmission Electron Microscopy Method*, was issued in 1995 (ISO, 1995). This TEM method is used in determining the concentration of asbestos structures in both indoor and outdoor environments with appropriately loaded filters. TEM ISO structure recording rules differ from other TEM analysis methods (e.g., AHERA) in that there is a fairly complex set of rules for counting fibers that occur in complex structures (e.g., matrices, clusters), requiring enumeration of individual fibers when the fibers can be clearly distinguished, and counting the complex particles as a unit when the individual fibers cannot be clearly resolved. A limitation of this method in analyzing samples at Libby is that the method does not discriminate between asbestos and non-asbestiform amphiboles. ISO 10312 recognizes this (Section 1:1): “The method cannot discriminate between individual fibers of the asbestos and non-asbestos (meaning non-asbestiform) analogues of the same amphibole mineral”. This means that the analysis counts include asbestos fibers, cleavage fragments, and other non-asbestiform particles in the asbestos count (provided the dimensional and EDS requirements are met). Such structures, including non-asbestiform fibers, are recorded for the Libby Site as “Total LAA” structures. “Total LAA” includes both asbestos and non-asbestiform analogues of the same amphiboles and often includes structures with widths and lengths outside the range that can be detected by PCM (total includes all structures with a length ≥0.5 µm and an aspect ratio of ≥3:1). When considering the risk associated with the presence of LAA, “PCME LAA” counts are utilized.

Under TEM ISO recording rules, a fiber is defined as “an elongated particle which has parallel or stepped sides, an aspect ratio ≥5:1, and a minimum length of 0.5 µm”. At the Libby Site, EPA has varied the aspect ratio rule over time (e.g., Libby laboratory modification #LB-000016 and #LB-000016A). However, for samples collected in support of the OU3 Study Area, TEM analyses have employed an aspect ratio rule of ≥3:1, as recommended in EPA’s Asbestos Framework (2008) “to mimic the size fraction of fibers that would be detected if the sample were being run under PCM”. The laboratories have also followed EPA’s other Libby-specific laboratory modifications for the identification and counting of asbestos fibers and QC requirements (e.g., #LB-000029, #LB-000066, #LB-000067, #LB-000085).

At the Libby Site, TEM ISO is typically used as the principal recording method for investigative samples (e.g., ABS, ambient air monitoring). Although ISO 10312:1995(E) is written as an analytical method for air filters that are directly prepared, at the Libby Site and at the direction of EPA, this method has also been utilized to specify the desired recording rules for air samples that have been prepared indirectly (per SOP EPA-LIBBY-08 and detailed below) and for the TEM analysis of other non-air media, such as dust, tree bark, duff, ash, soil, water, and tissue.

In SAPs involving the collection and analysis of air samples from ABS, EPA specified that if an air filter sample is deemed to be unevenly loaded or overloaded (particulate coverage of greater than 25% on the filter) then the air filter will be prepared indirectly (usually with ashing) in accordance with Libby Asbestos Site-specific procedures, such as those set forth in SOP EPA-LIBBY-08, *Indirect Preparation of Air and Dust Samples for Analysis by TEM*, as modified by Libby-specific laboratory modification #LB-000091. In some instances, EPA also has specified that an air sample will be prepared indirectly if there is loose material in the cowl of the air cassette. In accordance with SOP EPA-LIBBY-08, the ashed residue from the original filter is suspended in water and sonicated. An aliquot of this water is applied to a second filter, which is then used to prepare a set of TEM grids. To account for the amount of dilution inherent in indirectly prepared samples, EPA incorporates a dilution factor or F-factor (which is used to calculate the achieved analytical sensitivity) in reported air concentrations from such samples. Application of these indirect preparation techniques has the potential to change the nature of any asbestos fibers that may have been present on original filter, because the sonication step can dissociate fibers present in complex structures as well as break or split fibers into smaller particles. Indirect preparation techniques have also been developed by the EPA Region 8 for use at the Libby Site on media, such as duff and tree bark.

As discussed in the *Final LAA HHRA* (EPA, 2015a), EPA has developed an adjustment factor to account for the effect of indirect preparation on reported LAA air concentrations. The adjustment factor is based upon EPA Site-specific studies that observed a 2-4 factor increase in reported PCME LAA air concentrations for indirectly prepared filters as compared to direct preparation. For the purposes of calculating exposure point calculations (EPCs) for determining risk, an indirect preparation adjustment factor of 2.5 was used by EPA to account for the probable bias in air concentration estimates resulting from the use of an indirect preparation method. Additional information on the development of this adjustment factor can be found in Appendix D of the *Final LAA HHRA.*

EPA 100.2. *Determination of Asbestos Structures over 10 μm in Length in Drinking Water,* (EPA, 1994b) is a method for the preparation and analysis of water samples by TEM. This method is derived from EPA 100.1, *Analytical Method for Determination of Asbestos in Water*. The principal difference between the recording rules specified in these methods is that EPA Method 100.1 records all asbestos structures, whereas EPA Method 100.2 records only those asbestos structures that are longer than 10 µm, which is the basis for asbestos fibers regulated by the maximum contaminant level for asbestos in drinking water. However, identification and measurement of all asbestos fibers (both greater and less than 10 µm) may be required. In such cases, EPA Method 100.2 specifies a modified filter membrane size to prevent the loss of small fibers during filtering. In general, the structure recording rules for both methods are similar to those utilized by TEM ISO in that higher order structures (e.g., matrices, clusters) are disaggregated to enumerate individual fibers when they can be clearly distinguished.

In accordance with the method, if the collected water is not filtered within 48 hours, samples undergo special preparation methods to address bacterial and algal growth that may influence

the reporting of structures in the TEM analysis. In brief, sample preparation includes an ozonation/ultraviolet light (UV) treatment and sonication step, which is designed to oxidize organic matter present in the water or on the walls of the bottle, thus destroying any material that might cause clumping and binding of asbestos structures. Beginning in July of 2010 (per Libby laboratory modification #LB-000020a), all water samples were prepared using the ozonation/UV treatment regardless of the elapsed time between sample collection and filtration.

3.5.2 Non-asbestos Analytical Methods

EPA-approved non-asbestos sample test methods were utilized for various sample media collected at in the OU3 Study Area. When necessary, the analytical methods were incorporated into project-specific SOPs. The analytical methods used to analyze samples of various media in the OU3 Study Area for non-asbestos constituents are presented in **Table 3-2**.

3.6 QUALITY ASSURANCE / QUALITY CONTROL

The purpose of this section is to describe the QA and QC procedures that have been established to govern the collection and analysis of samples in the OU3 Study Area to confirm that the reported data are valid and useable. Refer to the *Libby Asbestos Superfund Site Operable Unit 3 Data Summary Report: 2007 to 2014 – Revision 3* (referred to herein as *DSR*; CDM Smith, 2016) for a summary of results for a variety of different types of QA/QC samples that have been collected across the various sampling programs and within the laboratory that provide information on the accuracy, precision, and reliability of reported results.

3.6.1 Field Quality Assurance Activities

General. Field QA activities include processes and procedures that have been designed to confirm that field samples are collected and documented properly, and that any issues/deficiencies associated with field data collection or sample processing are quickly identified and rectified. Detailed information on field QA activities can be found in the investigation-specific SAP/QAPPs. These SAP/QAPPs are developed by the EPA technical support contractors and implemented by Grace field contractors. The following bullets summarize the components of the field QA program implemented in the OU3 Study Area.

- **Field Team Roles/Responsibilities –** There are a variety of field personnel involved in the sampling investigations for the OU3 Study Area and each individual has assigned roles and responsibilities. The field team leader (FTL) oversees sample collection activities to ensure that governing documents are implemented appropriately. The field QA manager is responsible for ensuring that field efforts are conducted in accordance with appropriate QA guidelines.
- **Field Team Training -** Individuals involved in the collection, packaging, and shipment of samples must have appropriate training, including OSHA 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) and relevant 8-hour refreshers, respiratory protection, and asbestos awareness training.
- **Orientation –** Field personnel are required to attend an orientation session with the field Health and Safety (H&S) manager, as well as an orientation session on sample collection techniques.
- **Investigation-Specific Documentation** - Field personnel are required to review and understand applicable governing documents associated with the sampling

investigation, including the SAP/QAPP, associated SOPs, and the applicable Health and Safety Plan (HASP).

- **Readiness Reviews** - Meetings are conducted prior to beginning field sampling activities to discuss and clarify the objectives, equipment and training needs, field SOPs, QC samples, and H&S requirements for each investigation.
- **Field Documentation Review** – Field documentation is completed by field staff using investigation-specific field forms. These field forms provide a standardized method of documenting sample information generated in the field. Field documentation is reviewed on a regular basis to ensure the accuracy of the recorded sample information.
- **Equipment Maintenance/Calibration** – Field equipment is maintained in accordance with manufacturer specifications and the OU3 Study Area-specific SOPs. For air samples, each air sampling pump is calibrated to the desired flow rate using a primary calibration standard prior to sample collection.
- **Equipment Decontamination** – Field equipment used in sample collection is decontaminated in accordance with the OU3 Study Area-specific SOPs. Any disposable equipment or other investigation-derived waste (IDW) is handled in conformance with SOP requirements.
- **Sample Custody/Tracking** - Samples collected in the OU3 Study Area are tracked and managed in accordance with the OU3 Study Area-specific SOPs for sample custody and tracking using appropriate chain of custody (COC) forms.
- **Field QC Samples** - A variety of different types of field QC samples have been collected as part of the investigations conducted in the OU3 Study Area. These QC samples provide information on potential contamination arising from sample collection methods as well as information on result precision.
- **Modification Documentation** – Major deviations to the SAP/QAPP that modify the sampling approach and associated guidance documents are recorded on a field record of modification (ROM) form. These ROMs are reviewed and approved by the EPA remedial project manager (RPM).

Field Oversight. Because field sampling activities in the OU3 Study Area are performed by Grace contractors, an important component of the field QA program is field oversight. From 2007 to 2009, field oversight was provided by EPA's contractor, CDM Smith. Starting in 2010, field oversight has been performed by EPA's contractor, HDR Engineering, Inc. (HDR). Prior to initiating oversight activities, CDM Smith and/or HDR staff associated with the oversight activities reviewed governing investigation-specific documents and prepared blank audit checklists to be completed during the field oversight activities. Details on field oversight findings can be found in the *DSR* (CDM Smith, 2016).

3.6.2 Soil Preparation Laboratory Quality Assurance Activities

General. Until 2012, soil and sediment samples collected from the OU3 Study Area were sent to the CDM Smith Close Support Facility (CSF) in Denver, Colorado for preparation prior to analysis by the Libby-specific PLM methods. The *CSF Soil Preparation Plan* (CDM Smith, 2004) served as the guidance document for activities at the CSF. Beginning in 2012, soil/sediment samples collected from the OU3 Study Area were sent to the Sample Preparation Facility (SPF) in Troy, Montana for preparation prior to analysis by the Libby-specific PLM methods. The *SPF Soil Sample Preparation Work Plan* presented in Appendix F of the *Troy Asbestos Property Evaluation Work Plan* (Tetra Tech, EM Inc., 2007) serves as the guidance document for activities at the CSF. The purpose of the soil preparation plans (SPPs) is to provide standard guidance on preparation

methods to ensure that these procedures and resulting measurements were scientifically sound and of acceptable and documented quality. The following bullets summarize components of the QA procedures at the preparation laboratories.

- **Personnel Training** – Individuals involved in the processing of samples are required to have read and understood the SPP, associated SOPs, as well as the facility HASP. In addition, personnel must have appropriate training, including OSHA 40-hour HAZWOPER and relevant 8-hour refresher updates.
- **Documentation Review** – Sample preparation documentation is completed by preparation laboratory staff using Libby-specific forms. These forms provide a standardized method of documenting sample preparation information generated. This documentation is reviewed on a regular basis to ensure the accuracy of the recorded preparation information.
- **Equipment Maintenance/Calibration** – Weight scales, ventilation hoods, and drying ovens used in sample preparation are maintained and calibrated in accordance with manufacturer specifications. In addition, the plate grinder is calibrated daily, to verify proper particle size and demonstrate that samples are not being over-processed.
- **Equipment Decontamination** – Sample preparation equipment is decontaminated in accordance with Libby-specific preparation SOPs (ISSI-LIBBY-01 and 16-ASB-06.02) between each sample.
- **CSF Contamination Monitoring** – The preparation laboratory performs regular laboratory contamination monitoring to evaluate worker safety, ensure laboratory cleanliness, and help assess the potential for laboratory cross-contamination of samples submitted to the facility.
- **Sample Custody/Tracking** - Samples collected processed at the preparation laboratory are tracked and managed in accordance with COC requirements specified in the SPP.
- **Preparation QC Samples** - A variety of different types of preparation QC samples have been included in the preparation of sample collected as part of the investigations conducted in the OU3 Study Area. These QC samples provide information on potential laboratory contamination arising from sample preparation methods as well as information on result precision.
- **Modification Documentation** – Major deviations from the Libby-specific preparation SOP are recorded on a ROM form. These ROMs are reviewed and approved by the EPA RPM (or their designee).

3.6.3 Soil Preparation Laboratory Audits

The EPA QATS contractor, CB&I, performed audits of the CDM Smith CSF and the Troy SPF. Specific activities that were audited included the general laboratory facility, laboratory organization and personnel, general housekeeping, sample receipt and storage, sample preparation procedures, measurements and documentation, sample shipping procedures, and QA/QC procedures. Details on soil preparation laboratory audit results can be found in the *DSR* (CDM Smith, 2016).

3.6.4 Analytical Laboratory Quality Assurance Activities

General. Laboratories selected for analysis of samples for asbestos are part of the Libby analytical laboratory team. These laboratories have demonstrated experience and expertise in analysis of LAA in environmental media, and are part of an ongoing Libby-specific QA program designed to ensure accuracy of analytical and consistency of reported analytical results between laboratories. These laboratories are audited by the EPA QATS contractor and the National Institute of Standards and Technology (NIST)/National Voluntary Laboratory Accreditation Program (NVLAP) on a regular basis.

Laboratory QA activities include processes and procedures that have been designed to ensure that data generated by an analytical laboratory are of high quality and that any problems in sample preparation or analysis that may occur are quickly identified and rectified. The following bullets summarize the laboratory QA procedures that are required of each laboratory that analyzes samples from in the OU3 Study Area.

- **Laboratory QA Management Plan** - Each laboratory has developed a laboratory-specific QA Management Plan that provides a detailed description of the procedures and policies that are in place at their laboratory to ensure laboratory quality.
- **Certifications** - Analytical laboratories are subject to national, local, and project-specific certifications and requirements. Each laboratory is accredited by the NIST/NVLAP for the analysis of airborne asbestos by TEM and/or analysis of bulk asbestos by PLM. This includes the analysis of NIST/NVLAP standard reference materials (SRMs), or other verified quantitative standards, and successful participation in two proficiency rounds per year each of bulk asbestos by PLM and airborne asbestos by TEM supplied by NIST/NVLAP.
- **Team Training/Mentoring Program** - Laboratories are required to participate in a training/mentoring program to ensure laboratories can demonstrate the ability to perform reliable analyses at the Libby Site. The training process includes a review of morphological, optical, chemical, and electron diffraction characteristics of LAA using the Libby Site-specific reference materials, as well as training on project-specific analytical methodology, documentation, and administrative procedures used on the Libby Site.
- **Technical Discussions/Conferences** - Laboratories participate in regular technical discussions with the EPA and their contractors, as well as attend professional/technical conferences. These discussions enable the laboratory and technical team members to have an ongoing exchange of information regarding analytical and technical aspects of the project.
- **Analyst Training** - TEM and PLM analysts are required to undergo method-specific training and must understand the application of standard laboratory procedures and methodologies, including the Libby-specific analytical methods. Analysts must familiarize themselves with the Libby-specific method deviations, project-specific documents, and visual references.
- **Data Reporting** - Standardized bench sheets and data entry spreadsheets have been developed specifically for the Libby project to ensure consistency between laboratories in the presentation and submittal of analytical data. Analysts are trained in the project-specific reporting requirements and data reporting tools utilized in transmitting results.

- **Laboratory QC Samples** - A variety of different types of laboratory QC analyses have been collected as part of the investigations conducted in the OU3 Study Area. These QC analyses provide information on potential laboratory contamination arising from laboratory preparation and analysis methods as well as information on result accuracy and precision.
- **Laboratory Contamination Monitoring** – Each analytical laboratory performs regular laboratory contamination monitoring to evaluate worker safety and ensure laboratory cleanliness in compliance with their SOPs and certification requirements.
- **Modification Documentation** - Changes or revisions needed to improve or document specifics about analytical methods or laboratory procedures are documented using a ROM form. These ROMs are reviewed and approved by the EPA RPM (or their designee).

3.6.5 Analytical Laboratory Audits

Each laboratory conducts internal audits of their specific operations on an annual basis using appropriate checklists in accordance with their laboratory-specific QA Management Plan. As noted above, the laboratories that are part of the Libby analytical laboratory team are also audited by EPA's QATS contractor on a regular basis to specifically evaluate adherence to Libby-specific analytical requirements. The OU3 Study Area audits are used by the EPA to verify samples analyzed by their contract facilities are being processed in accordance with the EPA requirements. Each OU3 Study Area audit involves a review of the general elements of preparation, OU3 Study Area support, and report generation, which are modified as needed to fit the type of audit being performed. Details on analytical laboratory audit results can be found in the *DSR* (CDM Smith, 2016).

3.6.6 QC Results

There are a variety of field QC samples, preparation laboratory QC samples, and analytical laboratory QC analyses included as part of the sampling investigations performed in the OU3 Study Area. A detailed review and discussion of the results for QC samples and analyses is provided in the annual QA/QC summary reports for the OU3 Study Area prepared by EPA's QATS contractor. These reports are provided in **Appendix G,** summarized below, and detailed in the *DSR* (CDM Smith, 2016). The summaries below relate to data collected since 2007.

3.6.6.1 Field Quality Control Samples

The types of field QC samples collected as part of RI sampling activities for the OU3 Study Area after 2007 were specified in the in the investigation specific SAP/QAPPs and differ by media type, as follows:

- **Lot Blanks** – collected for air samples only. Since 2007, more than 20 air filter lot blanks have been analyzed by TEM and no asbestos structures were observed in any of the lot blanks analyzed. Based on lot blank results, the air filters used during the field sample collection did not contain asbestos.
- **Field Blanks** – collected for air and water samples. Since 2007, more than 100 field blanks have been collected and analyzed by TEM. LAA was not detected in any of the air field blanks. LAA was detected in three of the water field blanks; field samples collected on the same day as these field blanks were FB-qualified in the database. Based on the low number of detections (as compared to the number of

samples collected), the contamination of air samples and water samples as a consequence of field collection and analysis methods is not of concern.

- **Field Duplicates/Splits (air, water, duff material, tree bark)** – Since 2007, more than 100 field duplicate/splits have been collected for air, water, tree bark, and duff material and analyzed by TEM.. Because field duplicate/split samples are expected to have variability that is random and may be either small or large, there is no quantitative requirement for the unanimity of field duplicates/splits, instead results provide information on the magnitude of this variability and its effect on data interpretation. The TEM results of the field sample and the field duplicate/split are compared using the two Poisson rates method for comparison (Nelson, 1982). An evaluation of field duplicates/splits suggests that the TEM results for air samples is reproducible. Due to the inherent heterogeneity within the media, it is difficult to determine, the reproducibility of water, tree bark, and duff TEM results (even within a small sampling scale). Concentrations were usually within a factor of about 2 to 3 for water samples and within a factor of about 10 for tree bark and duff samples.
- **Field Duplicates/Splits (sediment, soil, soil-like media)** – Since 2007, more than 40 field duplicates for sediment, soil and soil-like media were collected and analyzed by PLM. The PLM-VE results for the original and field duplicate/split samples are compared to determine if both samples report results for the same semi-quantitative "bin". Overall concordance was generally good, with 100% concordance for PLM-Grav and about 80% concordance for PLM-VE. When PLM-VE field duplicate results were discordant, results were only weakly discordant (i.e., within one bin of each other).
- **Equipment Rinsates** – collected for groundwater samples only. Since 2007, 13 equipment rinsate samples were collected and analyzed by TEM. In 2008, total LAA was detected in one equipment rinsate; the field samples collected on the same day as the contaminated equipment rinsate sample were FB-qualified in the database. In 2015, total LAA was detected in all the collected equipment rinsates. As a consequence, groundwater results from the affected investigation were blank-adjusted to account for the possibility of cross-contamination in the field using the contaminated equipment (see Section 5.2.3 for more information).

3.6.6.2 Preparation Laboratory Quality Control Samples

The preparation laboratory QC samples are used to confirm that the preparation techniques utilized to process soil-like samples did not introduce potential laboratory contamination and to evaluate variability associated with preparation techniques. The types of preparation laboratory QC samples that were evaluated as part of the RI are:

- **Preparation Blanks** (including both grinding blanks and drying blanks) – Since 2007, more than 70 preparation blanks were analyzed by PLM-VE. All blank samples were non-detect for LAA indicating that the drying and grinding preparation procedures utilized with the preparation facilities did not introduce LAA into samples.
- **Preparation Duplicates** – Since 2007, more than 40 preparation duplicates were prepared by the preparation facilities and analyzed by PLM. Comparison of the preparation duplicates results with the paired field sample results aids to evaluate the variability that may occur during sample preparations and analysis. Most (~76%) of the preparation duplicates were ranked as concordant. When results were discordant, they were only weakly discordant (i.e., within one bin). These results suggest that the PLM-VE results are generally reproducible and reliable, and are not greatly influenced by

differences in laboratory preparation and analysis techniques. A total of 20 preparation duplicates pairs have been analyzed by PLM-Grav; the concordance rate was 100%.

3.6.6.3 Analytical Laboratory Quality Control Samples

The laboratory QC requirements for TEM analyses at the Libby Site are patterned after the requirements set forth by NVLAP, and include:

- **Laboratory Blanks** – Since 2007, more than 175 TEM laboratory blank analyses have been performed. No asbestos structures were observed in any laboratory blank sample. These results indicate that the filter preparation and analysis procedures utilized within the analytical laboratories likely did not introduce asbestos.
- **Re-preparation Analysis** – Since 2007, more than 50 re-preparation TEM analyses have been performed. Re-preparation analyses are compared to the original analysis using the two Poisson rates ratio method for statistical comparison recommended by Nelson (1982). Most (91%) of the re-preparation analyses performed were not statistically different from each other. These results show that LAA concentrations in air, tree bark, and duff reported in the OU3 Study Area investigations have acceptable reproducibility and that TEM analytical precision is not likely to be impacted by filter preparation methods. The reproducibility of water samples was ranked as poor historically, which highlights the inherent difficulties in sampling this medium. However, the reproducibility of water results has improved over time.
- **Recount Analyses** (i.e., recount same, recount different, and verified analyses) – Since 2007, more than 80 recount TEM analyses have been performed and more than 850 grid openings and 1,500 structure pairs have been re-examined. Recount analyses were compared with the original analysis on a grid opening-by-grid opening and structure-by-structure basis. Grid opening concordance is evaluated based on a comparison of total structure count. Structure concordance is evaluated based on a comparison of the assigned mineral classification and recorded structure dimensions. The total structure counts matched for approximately 93% of all grid openings, which ranks as acceptable concordance (per Libby laboratory modification #LB-000029). When the same structure was observed and recorded, there was 100% agreement on the assigned mineral class and good agreement (94% for length; 99% for width) on the recorded structure dimensions. These results indicate that there is good result reproducibility between TEM analysts within the same laboratory.
- **Inter-laboratory Analyses** – Since 2007, more than 50 inter-laboratory TEM analyses have been performed. More than 400 grid openings and 1,000 structure pairs have been re-examined as part of inter-laboratory analyses. Inter-laboratory analyses are recount analysis types in which grid openings are re-examined by a different laboratory than who performed the original analysis. Inter-laboratory analyses are compared in the same way as recount samples (described above). The total structure counts matched for only about 70% of all grid openings, which ranks as poor concordance (per Libby laboratory modification #LB-000029). When the same structure was observed and recorded, there was ~96% agreement on the assigned mineral class for paired structures, which is ranked as acceptable (per Libby laboratory modification #LB-000029). When mineral class differences were noted, it was usually related to differences in classification of “close call” non-asbestos material [NAM] (e.g., pyroxene). Although there was good agreement

(~98%) between laboratories on the recorded structure width, several discrepancies in recorded structure length were noted, and overall concordance was deemed acceptable at only (~83%). TEM inter-laboratory analyses indicate that differences between structure identification and recording procedures between the TEM laboratories are still evident. Explanations for the observed discordances included possible false negative results due to analyst error and/or misinterpretation, chemical variability among structures, and tears in the film replicate causing relocation of fibers.

Three types of laboratory-based QC analyses are performed for PLM-VE and include:

- **Laboratory Duplicates** (both self-checks and cross-checks) – Since 2007, more than 70 PLM-VE laboratory duplicate analyses have been performed. Comparison of the laboratory duplicate results with the paired original field sample results aids to evaluate the variability that may arise during the PLM analysis. Similar to preparation duplicates, laboratory duplicates are ranked as concordant if both the original sample results and the laboratory duplicate results display the same semi-quantitative classification. Nearly all (94%) of laboratory duplicates were ranked as concordant, with four analyses (6%) ranked as weakly discordant (i.e., within one bin of each other). These results indicate that the PLM-VE results are generally reproducible and reliable and are not greatly influenced by differences in analysis techniques within a PLM laboratory.
- **Inter-laboratory Analyses** – Since 2007, more than 30 PLM-VE inter-laboratory analyses have been performed. In general, the reproducibility of results between PLM-VE laboratories was poor for OU3 Study Area samples, with 33% ranked as weakly discordant and about 5% ranked as strongly discordant, which ranks as acceptable (per Libby laboratory modification #LB-000073). Inter-laboratory analyses concordance has improved over time suggesting that the actions taken to reduce between-laboratory differences that were previously noted have resulted in PLM-VE data that are more reproducible and reliable.
- **Performance Evaluation (PE) Standard Analyses** - Libby-specific PE standards for soil have been created for use at the Libby Site. These PE standards were created by spiking soil with known quantities of LAA obtained from the former mine. More than 75 PE standard analyses have been performed by the PLM laboratories that support OU3. About 62% of all PE standard analyses were concordant with the expected bin classification (as determined from the nominal LAA level in the PE standard). When results were discordant, they were usually weakly discordant; however, there were two strong discordances noted for the highest PE standard, with reported results being biased low. These results demonstrate that PLM-VE results are generally accurate but there are inherent uncertainties associated with reported binned results.

3.6.7 Data Verification and Validation

3.6.7.1 Data Verification

A data verification review was performed for data collected as part of the OU3 Study Area RI from 2007 through 2015. The goal of the data verification was to identify and correct data reporting errors.

A verification of the field sampling data sheet (FSDS) information was performed for samples of all media types (collected through 2015) in basic accordance with SOP EPA LIBBY-11 (Revision 0). FSDS verification was performed for 100% of samples on a weekly basis when field documentation forms were submitted during each investigation. Documentation errors and omissions were noted during these reviews. Every issue identified was resolved by field personnel and the necessary corrections have been made to the project database.

A verification of the surface water, groundwater, ambient air, ABS air, ash, tree bark, and duff sample results analyzed by TEM in basic accordance with the ISO Method 10312:1995(E) (ISO, 1995) was performed in accordance with SOP EPA-LIBBY-09 (Revision 2). A verification of the sediment, soil, and mine waste sample results analyzed by the Libby-specific PLM-VE and PLM-Grav methods was performed in accordance with SOP-EPA-LIBBY-10 (Revision 0). This verification effort was based on the Libby OU3 project database and the final laboratory reports as provided by the analytical laboratories. The frequency of each verification per investigation event and media type are presented in Table 1 of the *Libby Asbestos Superfund Site Operable Unit 3 Data Verification Report: 2007 to 2015* is included in **Appendix G**.

Any discrepancies identified during data verification were ranked as either critical or non-critical. Critical issues are those that have the potential to influence the reported result interpretations and/or concentrations. Most of the issues identified during the data verification process were non-critical and the frequency of critical errors was generally low. Identified discrepancies were submitted to the field teams and/or analytical laboratories for rectification and the necessary changes were incorporated into the OU3 Study Area database. The complete *Libby Asbestos Superfund Site Operable Unit 3 Data Verification Report: 2007 to 2015* is included in **Appendix G**.

3.6.7.2 Data Validation

Unlike data verification, where the goal is to identify and correct data reporting errors, the goal of data validation is to evaluate overall data quality and to assign data qualifiers, as appropriate, to alert data users to potential data quality issues within the subset of the data evaluated. A detailed review and discussion of the data validation results is provided in the annual QA/QC summary reports for the OU3 Study Area (see **Appendix G**). The validation results are summarized below.

Non-asbestos. For the Phase I and Phase II investigations (2007-2009), the non-asbestos data validation was performed by EPA subcontractor, TLI Solutions, Inc. A summary of the non-asbestos data validation is provided in **Appendix G**. In brief, inorganic, organic, and/or radiochemistry data for a total of 651 water and soil-like media samples in 29 sample delivery groups were reviewed by TLI. Over 3,400 analyses were assigned a data qualifier. The majority of these qualifiers (~98%) were assigned to denote estimated results (J-qualified) and non-detects (U-qualified); less than 2% of the qualified data were R-qualified (rejected) by the data validator. Any results that were R-qualified (rejected) by the data validator were excluded from use as the data are not reliable.

In 2015, EPA's QATS contractor, CB&I, validated 154 water analyses for inorganics, chloride/sulfate, and alkalinity methods. A summary of this validation effort is provided in **Appendix G**. Qualifiers were applied to 54 of the 154 analyses validated. All qualified samples were related to the metals and chloride/sulfate methods, with a lack of serial dilutions performed being the main cause for qualification. All of the assigned qualifiers were to denote estimated results (J-qualified) and non-detects (U-qualified); no results were R-qualified (rejected) by the data validator.

The OU3 Study Area database includes all assigned data validation qualifiers for non-asbestos constituents.

Asbestos. CB&I also performs a formal data validation on approximately 5% of the asbestos laboratory jobs each year. Samples for validation were selected randomly, choosing samples that were representative across each laboratory, analysis method, and medium. Since 2007, more than 2,000 analyses have been validated and very few asbestos data were qualified.

The OU3 Study Area database includes all assigned data validation qualifiers for asbestos results.

4 SUMMARY OF STUDY AREA INVESTIGATIONS

4.1 INTRODUCTION

This section presents a summary of the RI data-collection activities performed between September 2007 and September 2015. To date, the RI has been performed in a phased approach as summarized below. Each phase of data collection was performed in accordance with phase-specific SAPs and QAPPs developed and/or approved by the EPA.

Phase I of the RI was performed in the fall of 2007. The primary goal of the Phase I investigation was to obtain preliminary data on the levels and spatial distribution of LAA and non-asbestos constituents that potentially could have been released to the environment in the past as a result of the mining and milling activities that took place at the Former Mine Area.

Phase II of the RI was performed in the spring, summer, and fall of 2008. Phase II was comprised of three parts, as follows: Part A focused on the collection of data on the levels of LAA and non-asbestos constituents in surface water and sediment, as well as the OU3 Study Area-specific toxicity testing of surface water using rainbow trout. Part B focused on the collection of data on LAA levels in ambient air samples collected near the Former Mine Area, and on the collection of data on LAA and non-asbestos constituents in groundwater. Part C primarily focused on the collection of aquatic habitat and community data and the OU3 Study Area-specific toxicity tests to support the ecological risk assessment at the OU3 Study Area. This phase also included the collection of data on the levels of LAA and non-asbestos constituents in surface water and sediment at selected reference stations.

Phase III of the RI was performed in the spring, summer, and fall of 2009. Phase III included the collection of activity-based air samples during simulated recreational visitor activities in the forested area, as well as the collection of a variety of ecological community and habitat metrics in support of the ecological risk assessment.

Phase IV of the RI was performed in 2010 and 2011. Phase IV was comprised of two parts: Part A of the Phase IV SAP was performed in the summer and fall of 2010. Part A focused on the collection of additional activity-based air samples during simulated recreational visitor, wood harvesting, forest management, and firefighting activities to support the HHRA. Part B of the Phase IV SAP was performed in the spring, summer, and early fall of 2011. Part B focused on the collection of additional data on LAA levels in surface water to support the ecological risk assessment. Data collection efforts also included sampling to better characterize the habitat suitability of the OU3 Study Area streams for fish.

Phase V of the RI was performed in 2012 and 2013. Part A of this sampling program included the collection of LAA levels in surface water, sediment, and activity-based air samples during simulated recreational visitor activities on the Kootenai River. Part B of this sampling program included a series of ecological studies to support the ecological risk assessment, included an amphibian toxicity test, an amphibian field assessment, two in-stream caged fish toxicity studies addressing eyed egg and juvenile life stages, a resident fish lesion study, and a fish tissue LAA burden assessment. The eyed-egg toxicity study was repeated in 2013 due to loss of specimens from field cages (EPA, 2013a).

Additional RI activities were performed in 2012, 2013, 2014, and 2015 that were not incorporated under any of the RI phases described above. These activities included: simulated open burning of duff material, wood-burning stove ash removal, VW removal action in the amphitheater area, wildfire monitoring and activity-based air sample collection, commercial logging activity-based air sample collection, nature and extent activity-based air sampling, nature and extent surface water and sediment sampling, nature and extent tree bark and duff sampling, low-intensity prescribed understory burn ABS, slash pile burn ABS, trespasser ABS, surface water and groundwater sampling, geotechnical and hydrogeological investigations, and the OU3 Study Area reconnaissance surveys to better understand the surficial geology and geomorphology of the LRC drainage area.

FSSRs were developed for sampling phases/events conducted prior to 2014 and provide a summary of sampling activities, locations, and sampling methods employed. Sampling results for OU3 Study Area investigations are detailed in the *DSR* (CDM Smith, 2016). Additionally, each of the key references associated with each sampling phase/event is provided in **Sections 4.2** through **4.14** discussions below.

The following **Sections 4.2** through **4.14** describe the sampling design of each sampling phase/event by media type. **Table 4-1** outlines the number of samples for various media collected by sampling phase/event. The station identification numbers (ID), station descriptions, sampling phase/event, and analyses conducted are provided on **Table 4-2.** The following sections summarize the sampling programs for each environmental medium sampled, the habitat and community evaluations, and the OU3 Study Area-specific toxicity tests conducted for the RI from September 2007 through September 2015.

4.2 SURFACE WATER INVESTIGATIONS

Surface water samples were collected in the OU3 Study Area as part of the Phase I, Phase II (Part A), Phase II (Part C), Phase IV (Part B), Phase V (Part A and Part B), OU4 Nature and Extent Study, 2013 *In situ* Surface Water, and 2015 Spring Water Sampling programs. Surface water samples were analyzed for a broad suite of analytes, including LAA and non-asbestos constituents. The following section summarizes the surface water sampling objective(s) and design of each sampling program conducted between 2007 and 2015. **Table 4-1** outlines the number of samples collected for surface water by sampling phase/event. **Table 4-2** provides the surface water sampling locations by station ID, description, sampling phase/event, and analyses conducted. Surface water sample locations that were analyzed for LAA and non-asbestos constituent are presented on **Figures 4-1a** and **4-1b** respectively. Detailed results for LAA and for non-asbestos constituents detected in surface water samples collected throughout the OU3 Study Area are provided and discussed in **Section 5.0.**

4.2.1 Phase I (2007) –Sampling Activities

The objective of the Phase I sampling program was to collect surface water data to obtain a preliminary characterization of the nature and extent of surface water potentially impacted by releases from historical mining, milling, and activities ancillary to mining and milling (e.g., subsequent handling and transport of mined material). In addition, the Phase I sampling program also conducted a visual survey to identify and sample springs and seeps emanating from waste rock areas.

Twenty-four (24) total surface water samples were collected at the following surface water areas:

- The tailings impoundment and toe drains;
- Mill Pond;
- Rainy Creek, Fleetwood Creek, and Carney Creek upstream of mine-disturbed areas;
- Fleetwood Creek and Carney Creek downstream of mine-disturbed areas;
- LRC below the Mill Pond and below Carney Creek; and
- Seeps and springs on or near the Former Mine Area.

The 24 surface water samples were analyzed for LAA, metals/metalloids, petroleum/hydrocarbons, and anions. In addition, a broad suite of analyses were performed for samples collected at two locations: the tailings impoundment toe drain (TP- TOE1) and LRC downstream of the confluence with Carney Creek (LRC-2). These locations were selected because they have the best potential of characterizing releases from the mine. The additional analyses at these two locations included PCBs, pesticides, herbicides, gross alpha/gross beta, VOCs, semi-volatile organic compounds (SVOCs), polycyclic aromatic hydrocarbons (PAHs), and cyanide. The following water quality parameters were measured using field-portable instruments at the time of sample collection: temperature, pH, SC, DO, oxidation/reduction potential (ORP), and turbidity. Stream flow also was measured at the time of sample collection using a portable field meter.

Table 4-1 outlines the number of surface water samples collected in Phase I. **Table 4-2** provides the surface water sampling locations by station ID, station description, and analyses conducted for surface water samples collected in Phase I. Surface water sample locations that were analyzed for LAA and non–asbestos constituents are presented on **Figures 4-1a** and **4-1b,** respectively.

Samples were collected in accordance with the *Phase I Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site* (EPA, 2007b).

After the surface water samples were collected in the field, the samples for LAA analysis were hand-delivered to the EMSL Mobile Laboratory in Libby (which was staffed by EMSL Analytical, Inc. [EMSL[4]]) for filtration. Subsequent to this study, the lab contracting vehicles changed and labs were no longer directly subcontracted by Grace. No treatment of the water was performed prior to the filtration; however, most samples were filtered within 48 hours. The resulting filters were analyzed for total LAA by TEM. Filters were prepared and analyzed using EPA Method 100.2 (EPA, 1994b), with modified counting procedures as described in Libby Laboratory Modification #LB-000020.

Analyses of non-asbestos constituents in surface water were performed by Energy Laboratories, Inc. (ELI) in Billings, Montana.

Detailed information on the Phase I field sampling effort, including all associated field documentation, is provided in the *Phase I FSSR* (MWH, 2007) and the results are summarized in **Section 5.0** of this report.

[4] EMSL Libby closed in 2014.

4.2.2 Phase II, Part A (Spring-Fall 2008) – Sampling Activities

Data from the Phase I sampling program provided information on the concentrations of LAA and other non-asbestos constituents in surface water for a single sampling event performed during October 2007. Because concentrations of analytes in surface water may vary over time, especially in cases where there are large fluctuations in flow (e.g., during spring runoff), the objective of the Phase II Part A sampling program was to collect additional data to characterize the temporal and spatial patterns of LAA and non-asbestos constituents in surface water. A total of 209 surface water samples were collected and analyzed for LAA and 56 surface water samples were collected and analyzed for non-asbestos constituents as described below.

The Phase II Part A sampling program consisted of two monitoring efforts, one for the Rainy Creek watershed and one for the Kootenai River. The Rainy Creek watershed monitoring effort was split into five elements as follows:

Element 1 Seasonal Monitoring. The purpose of this element was to measure stream flow and concentrations of LAA and non-asbestos constituents in surface water at the stations sampled in Phase I to characterize constituent concentrations during spring and summer flow conditions. Element 1 surface water samples were collected at 30 locations. Two rounds of sampling were completed, one in June 2008 and one in September 2008. All surface water samples were analyzed for LAA, metals/metalloids, petroleum hydrocarbons, and anions. In addition, a broad suite of analyses were performed for samples collected at the tailings impoundment toe drain (TP-TOE1) and LRC downstream of the confluence with Carney Creek (LRC-2). As noted previously, these locations were selected because they appeared to have the best potential of characterizing potential releases from the mine. The additional analyses at those two locations included PCBs, pesticides, herbicides, gross alpha/gross beta, VOCs, SVOCs, and cyanide. The following water quality parameters were measured using field-portable instruments at the time of sample collection: temperature, pH, SC, DO, ORP, and turbidity. Stream flow was also measured at the time of sample collection using a portable field meter.

Element 2 Spring Runoff Monitoring. The purpose of this element was to monitor stream flow and LAA concentrations in surface water at selected stations within the Rainy Creek watershed during the rising and falling limbs of the spring snowmelt-runoff hydrograph. Surface water samples were collected weekly at 12 stations (13 when water was flowing through the Tailings Pond spillway) beginning at the onset of rising stream flows in response to snowmelt, continuing through the spring high-flow season, and ending after the seasonal peak in flow was observed on Rainy Creek (from early April through mid-June 2008). All surface water samples were analyzed for LAA. Stream flow also was measured at the time of sample collection.

Element 3 Summer and Fall Monitoring. The purpose of this element was to provide ongoing information on LAA concentrations and stream flow rates downstream of LAA sources within the Rainy Creek watershed. Two LRC stations were sampled as part of Element 3, the station below Carney Creek (LRC-2) and the station near its discharge to the Kootenai River (LRC-6). Surface water samples were collected every two weeks at each station, beginning in mid-June and ending in mid-August 2008. All surface water samples were analyzed for LAA. Stream flow also was measured at the time of sample collection using a portable field meter.

Element 4 Continuous Precipitation and Flow Monitoring. The purpose of this element was to collect continuous precipitation and stream flow data. To accomplish this, a rain gauge was placed at the meteorological station on the Former Mine Area and Parshall flumes were installed at LRC-2, LRC-6, and CC-2.

Element 5 Collection of Surface Water for Toxicity Testing. The purpose of this element was to collect OU3 Study Area surface water for use in the OU3 Study Area-specific toxicity tests.

In addition to the Phase II Part A sampling program, samples also were collected at nine surface water locations in the Kootenai River. These locations were selected to provide surface water LAA concentrations upstream and downstream of Rainy Creek and to include river locations with the greatest potential for elevated LAA concentrations due to transport via Rainy Creek. Although the planned study included sampling during both high flow and low flow conditions, samples were only collected under low flow conditions due to safety concerns for sampling personnel during high flow. Surface water samples were analyzed for LAA.

Table 4-1 outlines the number of surface water samples collected in Phase II. **Table 4-2** provides the surface water sampling locations by station ID, station description, and analyses conducted for surface water samples collected in Phase II. Surface water sample locations that were analyzed for LAA and non–asbestos constituents are presented on **Figures 4-1a** and **4-1b,** respectively.

Samples were collected in accordance with the *Phase II Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site Part A: Surface Water and Sediment* (EPA, 2008c).

After surface water samples were collected, as described above, in the field, the samples for LAA analysis were hand-delivered to the EMSL laboratory in Libby, Montana Mobile laboratory for filtration. No treatment of the water was performed prior to the filtration; however, most samples were filtered within 48 hours. The resulting filters were then sent to EMSL in Libby, Montana and Beltsville for analysis of total LAA by TEM. Filters were prepared (water was filtered) and analyzed according to the ISO method 10312:1995(E) (ISO, 1995) counting protocols, with all applicable Libby Site-specific laboratory modifications. Analyses of non-asbestos constituents in surface water were performed by ELI.

Detailed information on the Phase II Part A field sampling effort, including all associated field documentation, is provided in the *Phase II FSSR* (MWH, 2009) and the results are summarized in **Section 5.0** of this report.

4.2.3 Phase II, Part C (Fall 2008) – Sampling Activities

The objective of the Phase II Part C sampling program was the collection of aquatic habitat and community data and collection of surface water to support the OU3 Study Area-specific aquatic toxicity tests needed to support the ecological risk assessment in the OU3 Study Area. In addition, this sampling program also included the collection of surface water samples for aquatic bioassays at two selected aquatic reference stations, Noisy Creek (NSY-R1) and a tributary to Bobtail Creek (BTT-R1).

Two surface water samples were collected, one from each aquatic reference station, in October 2008. All surface water samples were analyzed for LAA, metals/metalloids, pesticides, herbicides, and SVOCs. At the time of sample collection, temperature, pH, SC, DO, ORP, turbidity, and stream flow also were measured in the field.

Table 4-1 outlines the number of surface water samples collected in Phase II Part C. **Table 4-2** provides the surface water sampling locations by station ID, station description, and analyses conducted for surface water samples collected in Phase II Part C. Surface water sample locations

that were analyzed for LAA and non–asbestos constituents are presented on **Figures 4-1a** and **4-1b,** respectively.

Samples were collected in accordance with the *Phase II Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site Part C: Ecological Data* (EPA, 2008d).

After water samples were collected in the field, the samples for LAA analysis were hand-delivered to the EMSL Mobile Laboratory in Libby for filtration. No treatment of the water was performed prior to the filtration however; most samples were filtered within 48 hours. The resulting filters were then sent to EMSL in Libby, Montana for analysis of total LAA by TEM. Filters were prepared and analyzed in accordance with ISO 10312:1995(E) (ISO, 1995) counting protocols, with all applicable Libby Site-specific laboratory modifications. Analyses of non-asbestos constituents in surface water were performed by ELI.

Detailed information on the Phase II Part C field sampling effort, including all associated field documentation, is provided in the *Final Data Report for the Autumn 2008 Aquatic Data Collection Program* (Parametrix, 2009a). Methods and results of the aquatic toxicity bioassays are summarized in the *Toxicity of Asbestos in Waters from the Libby Superfund Site Operable Unit 3 (OU3) to Rainbow Trout (Oncorhynchus mykiss)* (Parametrix, 2009b) and also are summarized in **Section 5.0** of this report.

4.2.4 Phase IV, Part B (2011) – Sampling Activities

The objective of Phase IV Part B focused on the collection of additional OU3 Study Area surface water data needed to support the ecological risk assessment. Data collection efforts included sampling and analysis of the OU3 Study Area surface waters to characterize temporal LAA concentrations, as well as efforts to better characterize the habitat suitability of the OU3 Study Area streams for fish. Because surface water samples collected as part of the Phase I and Phase II sampling investigations may have been influenced by fibers clumping and adhering to sample container walls, LAA concentration values observed in these samples were deemed uncertain. A second objective of the Phase IV Part B sampling program was to collect additional surface water data to better characterize temporal LAA concentrations in surface water at the OU3 Study Area using ozonation/ UV light treatment prior to filtration to address potential fiber clumping/wall adherence issues (EPA, 2011a).

The Phase IV Part B sampling program consisted of regular monitoring of LAA concentrations in surface water at a subset of the previously established sampling locations. This included locations where Parshall flumes had been placed, including two stations in Rainy Creek (LRC-2 and LRC-6) and one station in Carney Creek (CC-2), and at the tailings impoundment (TP). These stations were selected because LRC is the chief reach of concern for fish, and these stations are downstream of potential primary sources of LAA, including the tailings disposal area (LRC-2), sediments deposited along LRC (LRC-6), and seeps and ponds (CC-2). Station TP (in the tailings impoundment) was selected because it is representative of waters to which amphibians may be exposed. In order to characterize the levels of LAA in surface water as a function of flow, time (season), and location; weekly sampling was conducted from mid-April (prior to the onset of rising stream flows in response to snowmelt) to July 2011 at each station, followed by bi-weekly sampling after spring flows decreased through the end of September 2011. Eighty-two total samples were collected for LAA analysis, 10 of which were collected using a syringe and then immediately filtered through a syringe filter disk in the field. Only free fibers (i.e., fibers not associated with organic material clumps) were counted.

Whenever grab samples of surface water were collected, the in-stream temperature, pH, SC, DO, ORP, and turbidity also were measured using portable field meters. In addition, continuous flow monitoring was performed at LRC-2, LRC-6, and CC-2.

Table 4-1 outlines the number of surface water samples collected in Phase IV Part B. **Table 4-2** provides the surface water sampling locations by station ID, station description, and analyses conducted for surface water samples collected in Phase IV Part B. Surface water sample locations that were analyzed for LAA are presented on **Figure 4-1a**.

Samples were collected in accordance with the *Phase IV Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site Part B: 2011 Surface Water Study* (EPA, 2011a).

After water samples were collected in the field, the samples for LAA analysis were hand-delivered to the EMSL Mobile Laboratory in Libby for treatment (ozonation/UV light) and sonication in accordance with the procedures in EPA Method 100.1 prior to filtration. The resulting filters then were analyzed at the EMSL in Libby or Hygeia for analysis of total LAA by TEM in accordance with the ISO 10312:1995(E) (ISO, 1995) counting protocols, with all applicable Libby Site-specific laboratory modifications.

Detailed information on the Phase IV Part B field sampling effort, including all associated field documentation, is provided in the *Phase IV Part B FSSR* (MWH, 2013b) and the results are summarized in **Section 5.0** of this report.

4.2.5 Phase V, Part A (2012) – Sampling Activities

The objective of Phase V Part A sampling was the characterization of the potential nature and extent of LAA in surface water in the Kootenai River downstream of the confluence with Rainy Creek to address limitations identified with the existing data. As specified in the SAP/QAPP (EPA, 2012c), previous surface water data were collected during low flow conditions (no data were available under high flow conditions) and the collected water samples were not treated with ozone or UV light prior to filtration, which may have caused the LAA fibers to clump and adhere to the walls of the sample containers. In addition, previous Kootenai River water collection efforts only included a limited number of sampling locations. The overall objective of this investigation was to provide information to better characterize levels of LAA in the Kootenai River under both high flow and low flow conditions and to provide data that can be used to evaluate if concentrations of LAA in surface water in the Kootenai River downstream of the confluence with Rainy Creek are above a level of human health concern.

Relative loading from Rainy Creek to the Kootenai River is dependent upon numerous factors. As shown in previous studies, LAA concentrations in Rainy Creek tend to be higher in the spring when flow is highest (EPA, 2012c). The timeframe for the Phase V Part A sampling events spanned seasonal high flow conditions (i.e., spring run-off) from Rainy Creek to the Kootenai River so as to capture peak loading to the Kootenai River. Because Rainy Creek is potentially one of the sources of LAA to the Kootenai River, surface water grab samples were collected both upstream and downstream of the confluence with Rainy Creek to characterize the potential effect of Rainy Creek on the river. Surface water grab samples were collected from stations UKR-0, KR-1, KR-4, KR-5, and LRC-6 over an eight week period from late April 2012 through mid-June 2012, at a frequency of one sample per week. In order to evaluate low flow conditions, one surface water grab sample also was collected from each of these locations in mid-September 2012.

In addition to the samples listed above, five locations (KR-14, KR-15, KR-16, UKR-1, and UKR-3) were sampled once in late May 2012 and once in September 2012 during high and low flow periods. Surface water grab samples were collected from the bank at all locations. Additionally, at locations KR-14 and KR-16, river-transect surface water samples (four samples at equally-spaced intervals across the river) were collected using a flat-bottom powerboat on the same day that the grab samples were collected from the bank. A total of 72 surface water samples were collected and analyzed for LAA.

Table 4-1 outlines the number of surface water samples collected in Phase V Part A. **Table 4-2** provides the surface water sampling locations by station ID, station description, and analyses conducted for surface water samples collected in Phase V Part A. Surface water sample locations that were analyzed for LAA are presented on **Figure 4-1a**.

Samples were collected in accordance with the *Sampling and Analysis Plan / Quality Assurance Project Plan for Operable Unit 3, Libby Asbestos Superfund Site Phase V, Part A: Kootenai River Surface Water, Sediment, and Activity-based Sampling* (EPA, 2012c).

After the water samples were collected in the field, the samples were hand-delivered to the EMSL laboratory in Libby for filtration and analysis. Prior to filtration, all samples underwent ozonation/UV treatment and sonication in accordance with the techniques in EPA Method 100.2 (EPA, 1994b), as modified by Libby Laboratory Modification LB-000020A.

Resulting filters from high-flow samples were used to prepare grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E). These grids were initially examined by rapid turn-around analysis (TAT) by TEM in accordance with the procedures described in the OU3 Study Area-specific method modification (TEM_WATER_Mod1). In brief, grids were examined by TEM in accordance with the counting rules specified in ISO 10312:1995(E), but the analyst was not required to report structure-specific attributes for each countable structure observed. Rather, the analyst was only required to report the total number of countable LAA structures for each grid opening examined, which was then used to estimate the total LAA water concentration.

Originally, the intent was to utilize the results of the rapid turnaround time TEM analyses to identify the three-week time period when concentrations of LAA in the Kootenai River were the highest. Then, all samples collected within this three-week time period were to be analyzed by the "standard" TEM method and other samples outside of this three-week time period would be archived for possible future analysis. However, based on a preliminary evaluation of the rapid turnaround time results, the EPA decided that, with the exception of a subset of samples from locations LRC-6 and UKR-0, all samples would undergo standard TEM analysis. For locations LRC-6 and UKR-0, samples from the last three rounds of sampling during high flow conditions were archived.

During the "standard" TEM analyses, the prepared grids were examined by TEM in accordance with the procedures described in ISO 10312. Filters were analyzed in accordance with the ISO 10312:1995(E) (ISO, 1995) counting protocols, with all applicable Libby Site-specific laboratory modifications. Phase V, Part A surface water samples were not analyzed for non-asbestos constituents.

Continuous flow measurements were collected using ISCO® automated flow recorders installed at LRC-6, LRC-2 and CC-2. The data collected at LRC-6 was monitored to certify that the surface water samples were representative of high flow conditions within Rainy Creek.

Measurement of water quality parameters (e.g., pH, SC, etc.) and stream flow were not performed at Phase V, Part A surface water sample locations as stated in the SAP/QAPP (EPA, 2012c). Detailed sampling information, including all associated field documentation, is provided in the *Phase V Remedial Investigation FSSR* (MWH, 2013c) and the results are summarized in **Section 5.0** of this report.

4.2.6 Phase V, Part B (2012) – Study Activities

The objective of Phase V Part B 2012 was to conduct *in situ* eyed-egg toxicity test ecological studies in LRC and reference locations, which are located outside of the OU3 Study Area boundary, (refer to **Section 4.10.5** below for sample location details). The study was performed in May and June 2012. As part of this study, pore water samples from inside gravel buried Whitlock-Vibert box (WVB) chambers were collected (Pore Water [In]) to characterize LAA concentrations and evaluate whether exposure of the trout eggs or newly hatched fry to LAA in LRC presented an unacceptable ecological risk. In addition to the egg chamber pore water samples, a limited number of gravel pore water (Pore Water [Out]) external to the WVB and co-located overlying surface water in the WVB deployment location were collected. These two types of additional water samples were collected to evaluate the relationship between LAA concentrations in the WVB chamber, the gravel pore water immediately external to the WVB, and the overlying surface water. A total of 47 pore water samples were collected and analyzed for LAA.

Also as part of the Phase V, Part B 2012 studies, a juvenile trout toxicity test was performed during the same time period as the eyed egg study. Juvenile trout were maintained in secured, floating cages in the same locations as egg study within LRC and in reference streams. Surface water samples were collected to characterize LAA exposure concentrations within the cages to be utilized in the *Final Asbestos BERA* (EPA, 2014a).

Additionally, an Amphibian Field Study was conducted as part of the Phase V, Part B ecological studies SAP. Surface water samples in the OU3 Study Area ponds were collected as part of this study weekly once egg masses were estimated to be present starting on May 24, 2012 and ending on August 31, 2012. Surface water samples also were collected once each at study initiation and conclusion at each offsite reference pond. Water samples were submitted for analysis of LAA by TEM analysis method ISO 10312. See **Section 4.11.6** for sample location descriptions and further details on this study.

A total of 109 surface water samples were collected and analyzed for LAA as part of the juvenile trout toxicity and amphibian field study.

Samples were collected in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan Operable Unit 3, Libby Asbestos Superfund Site Phase V Part B: 2012 Ecological Investigations* (EPA, 2012d).

Table 4-1 outlines the number of surface water samples collected in Phase V Part B. **Table 4-2** provides the surface water sampling locations by station ID, station description, and analyses conducted for surface water samples collected in Phase V Part B. Surface water sample locations that were analyzed for LAA are presented on **Figure 4-1a**.

Detailed information on the Phase IV Part B field sampling effort, including all associated field documentation, is provided in the Golder Associates (Golder) *Data Report: 2012 In Situ Westslope*

Cutthroat Trout Toxicity Studies, Operable Unit 3; the *Data Report: 2012 Field Collection, Examination and Pathology of Amphibian Species* (Golder, 2013a; Golder, 2014a), and in **Section 5.0** of this report.

4.2.7 OU4 Nature and Extent Study in Surface Water and Sediment (2012) – Sampling Activities

Surface water and sediment samples (discussed below in **Section 4.4.6**) were collected in the spring and fall of 2012 as part of the OU4 RI to characterize the nature and extent of potential LAA contamination in surface water and sediment outside of the Rainy Creek Watershed. Sampling was conducted in the Kootenai River and its tributaries to evaluate the potential ecological and human health risks. This investigation was separated into two sampling efforts in an attempt to collect surface water data that were representative of both high flow (spring, May 2012) and low flow (fall; September 2012) conditions.

Only the Kootenai River surface water data collected as part of this activity are summarized in this report. The samples collected in the Kootenai River tributaries are not discussed. A total of six surface water samples were collected from the Kootenai River and analyzed for LAA.

Table 4-1 outlines the number of surface water samples collected in the OU4 Nature and Extent Study in Surface Water. **Table 4-2** provides the surface water sampling locations by station ID, station description, and analyses conducted for surface water samples collected in the OU4 Nature and Extent Study in Surface Water. Surface water sample locations that were analyzed for LAA are presented on **Figure 4-1a**.

Samples were collected in accordance with the *Surface Water and Sediment Sampling and Analysis Plan/Quality Assurance Project Plan* (EPA, 2012e).

All water samples were prepared for asbestos analysis in basic accordance with the techniques in EPA Method 100.2, as modified by Libby Laboratory Modification[1] LB-000020A. The resulting filters then were analyzed for total LAA by TEM analysis method ISO 10312, in accordance with the ISO 10312:1995(E) (ISO, 1995) counting protocols, with all applicable Libby Site-specific laboratory modifications.

Detailed information on the OU4 Nature and Extent Study in Surface Water field sampling effort, including all associated field documentation, is provided in the *Data Summary Report Nature and Extent of LA Contamination in Surface Water and Sediment* (EPA, 2013b) and the results are summarized in **Section 5.0** of this report.

4.2.8 Phase VB-2013 (2013), In-Situ Surface Water - Sampling Activities

The results from the 2012 eyed-egg study discussed above in **Section 4.2.6** were presented and evaluated in two technical memoranda (SRC, 2013; Golder, 2013a). However, interpretation of the study results was limited largely due to the number of organisms that went missing primarily as a result of WVB modification problems that lead to hatched alevin escape as well as ingress of predatory organisms.

Accordingly, the OU3 Study Area Biological Technical Advisory Group (BTAG) decided that it was necessary to repeat the in-stream eyed egg fish study in 2013, modifying the WVB structure to prevent ingress and egress from the chamber as well as increasing the monitoring frequency of the chambers. Samples of *in situ* surface water and pore water were collected twice weekly in

LRC and once weekly in reference creeks. A total of 38 pore water and 40 surface water samples were collected and analyzed for LAA.

Table 4-1 outlines the number of surface water samples collected in Phase VB-2013. **Table 4-2** provides the surface water sampling locations by station ID, station description, and analyses conducted for surface water samples collected in Phase VB-2013. Surface water sample locations that were analyzed for LAA are presented on **Figure 4-1a**.

The modifications were documented and sampling was collected according to the *Sampling and Analysis Plan/Quality Assurance Project Plan Addendum: Phase V, Part B: Ecological Investigations, Operable Unit 3, Libby Asbestos Superfund Site 2013 Repeat of In Stream Eyed Egg Study (Revision 0)* (EPA, 2013a).

Detailed information on the 2013 *In Situ* field sampling effort, including all associated field documentation, is provided in the *In Situ Westslope Cutthroat Trout Toxicity Study. Operable Unit 3, Libby Asbestos Superfund Site, Montana* (Golder, 2014b). The results are summarized in **Section 5.0** of this report.

4.2.9 ISCO Flows Measurements (2008-2015)

In August 2008, Parshall flumes were permanently installed in two concrete stations along Rainy Creek (LRC-06 and LRC-02), and one concrete station along Carney Creek (CC-02). The flume sizes at these three stations were selected based on the snowmelt runoff flows observed during spring 2008. Twelve-inch Parshall flumes were installed at stations LRC-06 and LRC-02, and a 9-inch flume was installed at station CC-02. A stilling well was attached to each of the flumes to house a pressure transducer for flow rate measurement and recording by an ISCO® Model 6712 portable sampler/data logger. Annual stream flow measurements have been collected since 2008 during the freeze-free part of the year, typically March through November. The raw flow data is uploaded to the Libby OU3 eRoom site bi-monthly (https://team.cdm.com/eRoom/mt/LibbyOU3/0_cfaf). **Table 2-8** presents the ISCO® station discharge rates and **Figure 2-6** graphically presents the ISCO® station locations and discharge rates in gpm versus month of the year for 2008 through 2015.

4.2.10 Surface Water and Groundwater Sampling (2015) – Sampling Activities

The 2015 Surface Water and Groundwater Sampling program consisted of the collection of samples from select surface water, groundwater (refer to **Section 4.3.3**), and toe drain water locations in the vicinity of the KDID. The objective of this program was to collect surface water samples to provide additional data to be utilized to more accurately evaluate, and better characterize, what source areas are contributing to LAA concentrations in LRC. Samples were collected for both LAA and non-asbestos general chemistry and metals constituents. These additional data were used to better understand how the KDID influences LAA concentrations in LRC by developing a more accurate hydrogeologic conceptual model. The data also will be used in the future in the development of remedial alternatives during the FS process to select alternatives that adequately address applicable OU3 Study Area water quality concerns. A total of 167 surface water samples were collected and analyzed for LAA and 28 surface water samples were collected and analyzed for non-asbestos constituents.

Table 4-1 outlines the number of surface water samples collected in the 2015 surface water and groundwater sampling program. **Table 4-2** provides the surface water sampling locations by station identification number (ID), station description, and analyses conducted for surface water

samples collected in the 2015 surface water and groundwater sampling program. Surface water sample locations that were analyzed for LAA and non–asbestos constituent are presented on **Figures 4-1a** and **4-1b** respectively.

Samples were collected in accordance with the *Sampling and Analysis Plan / Quality Assurance Project Plan for Surface Water and Groundwater Sampling* (MWH, 2015c).

For water samples being analyzed for LAA, after the water samples were collected in the field they were shipped to the EMSL laboratory in New Jersey. The EPA prepared grids were examined by TEM analysis method ISO 10312. Filters were analyzed in accordance with the ISO 10312:1995(E) (ISO, 1995) counting protocols, with all applicable Libby Site-specific laboratory modifications.

The water samples that were analyzed for non-asbestos general chemistry and metals were also shipped to the EMSL laboratory in New Jersey. General chemistry analytes included the major cations and anions. Total calcium, magnesium, sodium, and potassium were prepared using the appropriate methods and versions of the SW3005, SW3010, and SW3015 series methods, and analyzed using test method SW6010B. Method SW601B was selected over method EPA 200.7 to be consistent with the 2007 and 2008 surface water sampling events. Total chloride and sulfate were prepared and analyzed using test method E300.0 and alkalinity, bicarbonate, and carbonate were prepared and analyzed using test Method A2320 B.

Detailed information on the 2015 Surface Water and Groundwater Sampling, including all associated field documentation, is provided in the *2015 FSSR* (MWH, 2016b) and the results are summarized in **Section 5.0** of this report.

4.3 GROUNDWATER INVESTIGATIONS

A reconnaissance was completed in 2007 as Part of Phase I to locate and examine existing groundwater wells located within the Former Mine Area. **Table 2-5** presents the groundwater well construction details for those wells identified during the 2007 reconnaissance effort. Additionally, groundwater samples were collected in the OU3 Study Area as part of the Phase II Part B sampling program. Three rounds of groundwater sampling were performed in the summer and fall of 2008 and the spring of 2009. A more current groundwater sampling event was conducted in the spring of 2015. Groundwater samples were analyzed for a broad suite of analytes, including LAA and non-asbestos constituents. The following sections summarize the groundwater sampling efforts. **Table 4-1** outlines the number samples collected for groundwater by sampling phase/event. **Table 4-2** provides the groundwater sampling locations by station ID, description, sampling phase/event, and analyses conducted. Groundwater sample locations that were analyzed for LAA and non–asbestos constituent are presented on **Figure 4-2.** Detailed results for LAA and for non-asbestos constituents detected in groundwater samples collected throughout the OU3 Study Area are provided and discussed in **Section 5.0.**

4.3.1 Phase I (2007) – Groundwater Well Reconnaissance – Investigation Activities

A reconnaissance effort was conducted in the fall of 2007 (during the Phase I sampling program) to identify groundwater well locations within the Former Mine Area. A total of ten wells were identified within the vicinity of the OU3 Study Area. Wells A, C, D, E and H were selected for rehabilitated and redeveloped as part of the 2008 Phase II efforts. These wells were sampled as part of the Phase II Part B sampling program discussed below.

The reconnaissance effort was conducted in accordance with the *Phase I Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site* (EPA, 2007b).

4.3.2 Phase II Part B (2008 / 2009) – Sampling Activities

As part of Phase II Part B, groundwater samples were collected from wells A, D, and E in each of three sampling events, July 2008, September 2008, and June 2009. Groundwater samples were collected from Well C in September 2008 and June 2009, and from Well H in July 2008 and June 2009. No samples were collected from Well H in September 2008 (Round 2) because the well was dry. Fourteen groundwater samples were analyzed for LAA, and 13 groundwater samples were analyzed for metals/metalloids, petroleum hydrocarbons, anions, gross alpha/gross beta, and cyanide. If the total extractable petroleum hydrocarbon (EPH) concentration was above 300 micrograms per liter (µg/L), samples also were analyzed for specific EPH analytes (e.g., C9-C18 aliphatics, C19-C36 aliphatics, and C11-C22 aromatics) and PAHs. At the time of sample collection, field measurements of water quality parameters temperature, pH, SC, DO, ORP, and turbidity also were measured using portable field meters.

Table 4-1 outlines the number of groundwater samples collected in Phase II Part B. **Table 4-2** provides the groundwater sampling locations by station ID, station description, and analyses conducted for surface water samples collected in the Phase II Part B. Groundwater sample locations that were analyzed for LAA and non–asbestos constituent are presented on **Figure 4-2**.

Samples were collected in accordance with the *Phase II Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site Part B: Ambient Air and Groundwater* (EPA, 2008e).

After groundwater samples were collected in the field, the samples for LAA analysis were hand-delivered to the EMSL Mobile Laboratory in Libby for filtration (Note: No treatment of the water was performed prior to the filtration). The resulting filters were analyzed by EMSL at Libby, Montana for total LAA by TEM. Filters were prepared and analyzed in accordance with ISO 10312:1995(E) (ISO, 1995) counting protocols, with all applicable Libby Site-specific laboratory modifications.

Analyses of non-asbestos constituents in groundwater were performed by ELI.

Detailed information on the Phase II Part B field sampling effort conducted in 2008, including all associated field documentation, is provided in the *Phase II FSSR* (MWH, 2009) and the results are summarized in **Section 5.0** of this report.

4.3.3 Surface Water and Groundwater Sampling (2015) – Sampling Activities

The 2015 groundwater sampling program consisted of the collection of samples from select surface water (refer to **Section 4.2.10**), groundwater, and toe drain water locations (in the vicinity of the KDID), to more accurately evaluate, and better characterize, what source areas are contributing to LAA concentrations in LRC. Samples were collected for both LAA (20 samples) and non-asbestos (10 samples) general chemistry constituents at locations Well C, BH-01A-1, BH-01A-2, BH-03A-1, BH-05A-1, BH-05A-2, BH-07A-1, BH-07A-2, BH-07B-1, and BH-09-1. Locations BH-01B-1, BH-01B-2, BH-03B-2, and BH-05B-1 were dry when sampling was attempted. These additional data were used to better understand how the KDID influences LAA concentrations in LRC by developing a more accurate hydrogeologic conceptual model. The data

also will be used in the future in the development of remedial alternatives during the FS process to select alternatives that adequately address applicable OU3 Study Area water quality concerns.

Table 4-1 outlines the number of groundwater samples collected in the 2015 Surface Water and Groundwater Sampling program. **Table 4-2** provides the groundwater sampling locations by station ID, station description, and analyses conducted for surface water samples collected in the 2015 Surface Water and Groundwater Sampling program. Groundwater sample locations that were analyzed for LAA and non–asbestos constituent are presented on **Figure 4-2.**

Samples were collected in accordance with the *Sampling and Analysis Plan / Quality Assurance Project Plan for Surface Water and Groundwater Sampling* (MWH, 2015c). Refer to **Section 4.2.10** for analysis details.

Detailed information on the 2015 Surface Water and Groundwater Sampling, including all associated field documentation, is provided in the *2015 FSSR* (MWH, 2016b) and the results are summarized in **Section 5.0** of this report.

4.4 SEDIMENT INVESTIGATIONS

Sediment samples were collected in the OU3 Study Area as part of the Phase I, Phase II (Part A and Part C), Phase V (Part A and Part B), and the OU4 Nature and Extent Study sampling programs. Sediment samples were analyzed for a broad suite of analytes, including LAA and non-asbestos constituents. The following sections summarize the sediment sampling activities. **Table 4-1** outlines the number samples collected for sediment by sampling phase/event. **Table 4-2** provides the sediment sampling locations by station ID, description, sampling phase/event, and analyses conducted. Sediment sample locations that were analyzed for LAA and non–asbestos constituent are presented on **Figures 4-3a** and **4-3b** respectively. Detailed results for LAA and for non-asbestos constituents detected in sediment samples collected throughout the OU3 Study Area are provided and discussed in **Section 5.0.**

4.4.1 Phase I (2007) – Sampling Activities

The objective of the Phase I sediment sampling program was to collect data to obtain a preliminary characterization of the nature and extent of sediment potentially impacted by releases from historical mining, milling, and activities ancillary to mining and milling (e.g., subsequent handling and transport of mined material).Twenty-four (24) sediment samples were co-located with the surface water samples discussed above in **Section 4.2.1**. Each grab sample was collected from within a three-foot-square area and consisted of finer grained materials less than ¼ inch, and were from ground surface to a depth of six inches. The 24 samples were analyzed for LAA, metals/metalloids, petroleum hydrocarbons, and anions. A broad suite of additional analyses, including PCBs, pesticides, herbicides, VOCs, SVOCs, and PAHs, were performed for sediment samples collected from TP-TOE2 and LRC-2. These locations were selected because they appeared to have the best potential of characterizing possible releases from the mine.

Table 4-1 outlines the number of sediment samples collected in Phase I. **Table 4-2** provides the sediment sampling locations by station ID, station description, and analyses conducted for sediment samples collected in Phase I. Sediment sample locations that were analyzed for LAA and non–asbestos constituent are presented on **Figures 4-3a** and **4-3b** respectively.

Samples were collected in accordance with the *Phase I Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site* (EPA, 2007b).

After sediment samples were collected in the field, the samples for LAA analysis were sent to the CDM Smith CSF in Denver, Colorado for preparation. One aliquot of the fine ground material and one aliquot of the coarse fraction material were then shipped to EMSL at Libby, Montana for analysis of LAA by PLM.

Analyses of non-asbestos constituents in sediment were performed by ELI. Detailed information on the Phase I field sampling effort, including all associated field documentation, is provided in the *Phase I FSSR* (MWH, 2007) and the results are summarized in **Section 5.0** of this report.

4.4.2 Phase II, Part A (Spring / Summer 2008) – Sampling Activities

Data from the Phase I sampling program provided information on the concentrations of LAA and other non-asbestos constituents in sediment for a single sampling event (conducted in the fall of 2007). Because concentrations of analytes in sediment could vary over time, the objective of the Phase II Part A sampling program was to collect additional sediment data in the spring and summer of 2008 to characterize potential temporal and spatial patterns of OU3 Study Area-related analytes in sediment. A total of 116 sediment samples were collected and analyzed for LAA and 108 sediment samples were collected and analyzed for non-asbestos constituents.

Sediment sampling in the Rainy Creek watershed was conducted under "Element 1" of the Phase II Part A sampling program. The purpose of this element was to measure analytes in sediment at the stations sampled in Phase I to characterize levels during spring and summer flow conditions. This program differed from Phase I in that the tailings impoundment and each of the ponds (the Mill Pond and the ponds on Carney Creek and Fleetwood Creek) were sampled by collecting a composite of grab samples rather than a single composite sample. One composite sediment sample was collected from each sampling location and consisted of a composite of five grab samples collected from low-energy depositional portions of the stream channel that were submerged at the time of sampling from ground surface to a depth of four inches. These sample locations were focused mainly in areas that are typically or usually inundated with water, since these areas are most likely to serve as habitat for aquatic receptors. At the ponds (the Mill Pond and the ponds on Carney and Fleetwood Creeks), a total of five sediment grab samples were collected from each pond, including three samples from around the margins of the pond (at least three ft. from the edge) and two samples from near the center of the pond.

Two rounds of sampling were completed, one in June/July 2008 and one in September 2008. All sediment samples were analyzed for LAA, metals/metalloids, petroleum hydrocarbons, anions, and total organic carbon (TOC). Sediments from LRC (LRC-1 to LRC-6) and the tailings impoundment toe drain (TP-TOE2) were analyzed for PCBs to assess the potential impacts of oil used for dust control along the adjacent road. Sediment collected from TP-TOE2 and LRC-2 was also analyzed for VOCs, SVOCs, and cyanide.

The Phase II Part A sampling program also collected sediment samples in the Kootenai River. The samples were collected from low-energy depositional portions of the Kootenai River bank that was submerged beneath about one foot of water. In brief, the following samples were collected:

- Two grab samples from depositional areas located along the north bank of the Kootenai River upstream of the mouth of Rainy Creek.

- Two grab samples from depositional areas located along the north bank of the Kootenai River, within a distance of 0.5-mile downstream from the mouth of Rainy Creek.
- Two locations from the large gravel bar located in the center of the river about 0.5-mile downstream from the mouth of Rainy Creek. One location was on the highest portion on the gravel bar; the other location was at the downstream point of the gravel bar.

All Kootenai River sediment samples were analyzed for LAA.

Table 4-1 outlines the number of sediment samples collected in Phase II Part A. **Table 4-2** provides the sediment sampling locations by station ID, station description, and analyses conducted for sediment samples collected in Phase II Part A. Sediment sample locations that were analyzed for LAA and non–asbestos constituent are presented on **Figures 4-3a** and **4-3b** respectively.

Samples were collected in accordance with the *Phase II Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site Part A: Surface Water and Sediment* (EPA, 2008c).

After sediment samples were collected in the field, the samples for LAA analysis were sent to the CDM Smith CSF in Denver, Colorado for preparation. After preparation, samples were sent to EMSL at Westmont, New Jersey and Hygeia for analysis of LAA by PLM-VE (and polarized light microscopy, gravimetric [PLM-Grav], if a coarse fraction was present).

Analyses of non-asbestos constituents in sediment were performed by ELI.

Detailed sampling information, including all associated field documentation, is provided in the *Phase II FSSR* (MWH, 2009) and the results are summarized in **Section 5.0** of this report.

4.4.3 Phase II, Part C (fall 2008) – Sampling Activities

The Phase II Part C sampling program included the collection of samples at two of the three candidate aquatic reference stations, Noisy Creek (NSY-R1) and a tributary to Bobtail Creek (BTT-R1). In addition, sediment samples also were collected from a subset of stations in Rainy Creek (URC-1A, URC-2, LRC-2, LRC-3, LRC-5, and TP-TOE2), Fleetwood Creek (FC-2), and Carney Creek (CC-2) concurrently with the collection of the aquatic community surveys.

Twelve (12) total sediment samples were collected from each station in October 2008. All sediment samples were analyzed for LAA, metals/metalloids, TOC, pH, and total solids.

Table 4-1 outlines the number of sediment samples collected in Phase II Part C. **Table 4-2** provides the sediment sampling locations by station ID, station description, and analyses conducted for sediment samples collected in Phase II Part C. Sediment sample locations that were analyzed for LAA and non–asbestos constituent are presented on **Figures 4-3a** and **4-3b** respectively.

Samples were collected in accordance with the *Phase II Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site Part C: Ecological Data* (EPA, 2008b).

Detailed sampling information, including all associated field documentation, is provided in the *Final Data Report for the Autumn 2008 Aquatic Data Collection Program* (Parametrix, 2009a) and the results are summarized in **Section 5.0** of this report.

4.4.4 Phase V, Part A (2012) – Sampling Activities

The Phase V Part A investigation focused on characterizing the potential nature and extent of LAA in sediment at locations frequented by recreational visitors along the Kootenai River and Lake Koocanusa. Sediment samples were collected from two locations (KR-20, KR-21) in depositional areas of Kootenai River banks and sand bars. Samples were collected in September 2012, under low flow conditions when the most sediment was exposed. Each sediment sampling location was selected because it was representative of areas frequently used by recreational visitors. For location KR-20, which was also sampled as part of a recreational ABS effort (refer to **Section 4.8.3**), sediment sampling was performed prior to the start of each ABS event. Sediment samples also were collected from two locations along the banks of Lake Koocanusa, including the McGillivray Campground (LK-1) and the Lake Koocanusa Marina (LK-2).

Four (4) composite sediment samples comprised of 30 individual sampling points that were approximately equidistant from each other and representative of each recreational area were collected and analyzed for LAA. This sampling method accounts for spatial variability in LAA concentrations and provides an average estimate of the LAA concentration across the exposed area. Although observable / visible vermiculite notes were made at the time of sediment sample collection, these notes were inadvertently not completed by the field members collecting the samples in accordance with the visible vermiculite SOP identified in the governing SAP/QAPP (SOP CDM Smith-LIBBY-06); therefore, these notes are not presented in this report, but are available in the field log notes.

Table 4-1 outlines the number of sediment samples collected in Phase V Part A. **Table 4-2** provides the sediment sampling locations by station ID, station description, and analyses conducted for sediment samples collected in Phase V Part A. Sediment sample locations that were analyzed for LAA are presented on **Figure 4-3a**

Samples were collected in accordance with the *Sampling and Analysis Plan / Quality Assurance Project Plan for Operable Unit 3, Libby Asbestos Superfund Site Phase V, Part A: Kootenai River Surface Water, Sediment, and Activity-based Sampling* (EPA, 2012c).

Sediment samples were analyzed for LAA and were sent to the SPF located in Troy for processing in accordance with SOP ISSI-LIBBY-01. The fine ground aliquots for each sediment sample were analyzed by the EMSL laboratory in Libby using the Libby-specific PLM-VE method (SOP SRC-LIBBY-03). There were no coarse fractions for any of the sediment samples from this study.

Detailed sampling information, including all associated field documentation, is provided in the *Phase V Remedial Investigation FSSR* (MWH, 2013c) and the results are summarized in **Section 5.0** of this report.

4.4.5 Phase V, Part B (2012) – Sampling Activities

The Phase V Part B investigation focused on providing sediment data to support an amphibian metamorphic bioassay conducted for the OU3 Study Area. The goal of the amphibian laboratory toxicity test was to determine whether exposure of amphibians to sediment containing LAA would result in adverse effects on survival, growth, or metamorphosis. Amphibians may be exposed to

LAA in the aquatic environment both in water and sediment. This investigation focused on the evaluation of LAA exposures in sediment because previous attempts at surface water toxicity tests have shown that it is very difficult to maintain exposure conditions for LAA in surface water.

Sediment samples were collected from Carney Creek and Tailings Pond to determine which location had the highest LAA concentration to be used in the amphibian toxicity bioassay. Fifty four (54) total sediment samples were collected and analyzed for LAA and 12 sediment samples were collected and analyzed for metals, acid volatile sulfide, nitrogen compounds, diesel/gasoline range organics, and hydrocarbons.

Table 4-1 outlines the number of sediment samples collected in Phase V Part B. **Table 4-2** provides the sediment sampling locations by station ID, station description, and analyses conducted for sediment samples collected in Phase V Part B. Sediment sample locations that were analyzed for LAA and non–asbestos constituent are presented on **Figures 4-3a** and **4-3b** respectively.

Sediment was sampled in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan Operable Unit 3, Libby Asbestos Superfund Site Phase V Part B: 2012 Ecological Investigations* (EPA, 2012d). The sampling design for this investigation is detailed below in **Section 4.10.5**.

Results of this study are summarized in the *Amphibian Complete Metamorphosis Exposure Study, Libby Asbestos Superfund Site Phase V-B SAP, OU-3 Study Report* (Fort Environmental Laboratories, Inc., 2013) and in **Section 5.0** of this report.

4.4.6 OU4 Nature and Extent Study in Surface Water and Sediment (2012) – Sampling Activities

Surface water (discussed above in **Section 4.2.7**) and sediment samples were collected in the spring and fall of 2012 as part of the OU4 RI to characterize the nature and extent of potential LAA contamination in surface water and sediment outside of the Rainy Creek Watershed. Sampling was conducted in the Kootenai River and its tributaries.

Only the Kootenai River sediment data collected as part of this activity are summarized in this report. The samples collected in the Kootenai River tributaries are not discussed. Surficial sediment samples were collected at 12 locations from the Kootenai River, with each sample consisting of a composite of five grab samples. The samples were collected from low-energy depositional portions of the stream channel that were inundated by water at the time of sampling. The five grab samples were collected over an area that was within 100 ft. upstream or 100 ft. downstream of the specified station. A total of 12 sediment samples were collected and analyzed for LAA.

Table 4-1 outlines the number of sediment samples collected in the OU4 Nature and Extent Study. **Table 4-2** provides the sediment sampling locations by station ID, station description, and analyses conducted for sediment samples collected in the OU4 Nature and Extent Study. Sediment sample locations that were analyzed for LAA are presented on **Figure 4-3a**.

Samples were collected in accordance with the *Surface Water and Sediment Sampling and Analysis Plan/Quality Assurance Project Plan* (EPA, 2012e).

Sediment samples were sent to the SPF located in Troy for processing in accordance with SOP ISSI-LIBBY-01. Sediment samples were then sent to EMSL-Libby, EMSL-Cinnaminson, EMSL-Beltsville or EMSL-Denver for preparation and analysis for LAA. The fine ground and coarse fraction (if present) aliquots for each sediment sample were analyzed using the Libby-specific PLM-VE and PLM-Grav methods, respectively.

Detailed information on the OU4 Nature and Extent Study field sampling effort, including all associated field documentation, is provided in the *Data Summary Report Nature and Extent of LA Contamination in Surface Water and Sediment* (EPA, 2013b) and the results are summarized in **Section 5.0** of this report.

4.5 SOIL / MINE WASTE FROM THE MINED AREA INVESTIGATIONS

Sampling of soil/mine waste from the Former Mine Area was completed in October 2007 as part of the Phase I sampling program. These samples were analyzed for a broad suite of analytes, including LAA and non-asbestos constituents. Additionally, soil was sampled as part of the Amphitheater Removal Effort, geotechnical investigation, creek reconnaissance, and trespasser activity-based sampling. The following sections summarize these field sampling efforts. **Table 4-1** outlines the number of samples collected for soil/mine waste by sampling phase/event. **Table 4-2** provides the soil/mine waste sampling locations by station ID, description, sampling phase/event, and analyses conducted. Soil/mine waste sample locations that were analyzed for LAA and non–asbestos constituents are presented on **Figures 4-4a** and **4-4b,** respectively. Detailed results for LAA and for non-asbestos constituents detected in soil/mine waste samples collected throughout the OU3 Study Area are provided and discussed in **Section 5.0.**

4.5.1 Phase I (2007) – Sampling Activities

The objective of the Phase I soil/mine waste sampling activities was to collect samples from representative types of waste materials and soils in the Former Mine Area in order to identify analytes associated with mined materials and develop a list of source areas of potential concern. Thirty-eight (38) total mine waste samples were collected from:

- waste rock from various piles,
- surface soil,
- coarse tailings disposal area,
- tailings impoundment,
- outcrops, and
- materials used for construction of unpaved sections of Rainy Creek Road.

Each sample collected from the impounded tailings (MS-4 and MS-5) and the coarse tailings area (MS-6 to MS-9) was collected as an 8-point transect composite collected from the top 12 inches of material. All other samples were collected as surface (0-6 inches) grab samples. All 38 samples were analyzed for LAA and metals/metalloids. Waste rock, tailings, soil from the mill area located on the Former Mine Area, and roadway materials also were analyzed for petroleum hydrocarbons. The three samples of Rainy Creek Road base materials were analyzed for PCBs (based upon reports that oil had been used in the past to control dust on mine roads and PCB oils were present at the mine in the past). Samples collected from the fine tailings impoundment were analyzed for a broader suite of analytes, including pesticides, VOCs, SVOCs, PAHs, and cyanide, as well as PCBs, petroleum hydrocarbons, and anions.

Table 4-1 outlines the number of mine waste samples collected in Phase I. **Table 4-2** provides the mine waste sampling locations by station ID, station description, and analyses conducted for mine waste samples collected in Phase I. Mine waste sample locations that were analyzed for LAA and non–asbestos constituents are presented on **Figures 4-4a** and **4-4b,** respectively.

Samples were collected in accordance with the *Phase I Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site* (EPA, 2007b).

After soil samples were collected in the field, the samples for LAA analysis were sent to the CDM Smith CSF in Denver, Colorado for preparation. After preparation, samples were sent to EMSL at Libby, Montana and Westmont, New Jersey for analysis of LAA by PLM-VE (and PLM-Grav, if a coarse fraction was present).

Analyses of non-asbestos constituents in soil were performed by ELI.

Detailed information on the Phase I field sampling effort, including all associated field documentation, is provided in the *Phase I FSSR* (MWH, 2007) and the results are summarized in **Section 5.0** of this report.

4.5.2 Amphitheater Removal Effort (2012-2013) – Sampling Activities

The EPA entered into a second AOC with Grace and KDC in 2012 (EPA, 2012f; Docket No. CERCLA-08-2012-0004). Under the terms of this AOC, Grace performed a removal action at the OU3 Study Area, known as the Amphitheater Removal Effort.

The results of a field investigation conducted in October 2011 indicated that Rainy Creek flowed through an area containing VW located below the area referred to as the Amphitheater, which is located to the southwest of the Mill Pond. The VW was originally removed in 1994, as part of mine reclamation, from the Carney Creek sediment pond, which is located to the southeast of the Mill Pond. The material had been spread over the Amphitheater area as a soil substitute and re-seeded in 1995 (MDST, 1995). This area was a potential source of elevated LAA levels detected in LRC. To eliminate or mitigate this potential source of LAA to LRC, the LAA containing material was excavated and transported to the disposal area at the top of the former mine. This is the same area where LAA-bearing soil removed as part of the remediation of OU4, the town of Libby (refer to **Figure 2-17**), is placed before the soils are beneficially used for cover and vegetation management of the Former Mine Area. The removal action was performed in two phases of work, fall of 2012 and summer of 2013. Soil samples were collected as described below to support the removal efforts. The VW removal area and the VW disposal areas are presented on **Figure 4-4a**.

4.5.2.1 Summary of Sampling Activities

Existing OU3 Study Area Data. Prior to removal efforts, three characterization samples of the VW were collected from the affected area in October 2011 to establish the percentage of LAA in the waste material. The samples were analyzed by EMSL Laboratories in Libby, Montana by NIOSH PLM Method 9002, Issue 2. Further investigation of the nature, extent and thickness of the VW was performed in July 2012. A tire-mounted backhoe was used to excavate 19 test pits across the affected area. Two types of material were found in the test pits: a coarse-grained greenish black material (primarily located north of Rainy Creek), and a fine, powdery bronze-colored material, which was most prevalent south of Rainy Creek. Waste thickness ranged from

less than one inch near the margins to more than 5 ft. in berms and piles on the area south of Rainy Creek.

2012 Vermiculite Waste Removal Activities. Removal of the VW material was started in 2012 for six of 15 pre-defined zones. Once the VW material removal was complete for a zone, a 30-point composite characterization sample was collected from ground surface to one inch in depth (six composite samples in total) and submitted for LAA analysis.

2013 Vermiculite Waste Removal Activities. Removal of the VW material was completed in 2013 for the remaining nine of 15 pre-defined zones. Once the VW material removal was complete for a zone, a 30-point composite characterization sample was collected from ground surface to one inch in depth (nine composite samples in total) and submitted for LAA analysis.

Fifteen (15) total 30-point composite characterization soil samples were collected from ground surface to one inch in depth between the 2012 and 2013 activities, and submitted for LAA analysis. These samples were collected to confirm the removal action was complete.

Table 4-1 outlines the number of soil samples collected in the Amphitheater Removal Effort. **Table 4-2** provides the soil sampling locations by station ID, station description, and analyses conducted for soil samples collected in the Amphitheater Removal Effort. Soil sample locations that were analyzed for LAA (sample IDs that begin with "VW") are presented on **Figure 4-4a**.

Samples were collected in accordance with the *Work Plan for Removal of Asbestos-Containing Vermiculite Waste Near the "Amphitheater" at Libby Asbestos Superfund Site OU3 Part B; Sampling and Analysis Plan / Quality Assurance Project Plan* (MWH, 2012).

Samples were delivered to the SPF in Troy, Montana. Once the samples were prepared by the SPF, they were delivered to EMSL in Libby, Montana for analysis of LAA by PLM-VE (and PLM-Grav, if a coarse fraction was present).

Detailed information on the VW removal effort including all associated field documentation, is provided in the *Summary Report for Removal of Asbestos-Containing Vermiculite Waste Near the Amphitheater* (MWH, 2013d) and the results are summarized in **Section 5.0** of this report.

4.5.3 Land Farm Soil Analysis (2013) - Sampling Activities

The objective of the landfarm soil analysis event was to collect grab soil samples from the four corners and center of each of the two separate landfarm sections. Refer to **Section 2.11.1.2** for a discussion of the land farm background. These samples were collected under MDEQ Corrective Action ID 27-13196, Release 1729, Work Plan 7108 at the direction of the MDEQ.

Ten total grab soil samples were collected from approximately 1.5 ft. below ground surface (bgs), one sample from each location for a total of five grab samples per land farm section. The sampling events occurred in June 2013 and July 2013.

The soil samples were analyzed by ELI out of Billings, MT for:

- Resource Conservation and Recovery Act (RCRA) metals arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), lead (Pb) selenium (Se), and silver (Ag), using EPA method E6010.20

- RCRA metal mercury (Hg), using EPA method SW7471A.
- Volatile Petroleum Hydrocarbons (VPH), using EPA Methods SW5035 and MA-VPH,
- EPH, using EPA Methods SW8015M and SW3550B and SW3550A.
- Volatile Organic Compounds (VOCs), using EPA Method 8260B

The land farm soil sample area is presented on **Figure 2-16**.

Soil samples from the land farm were collected and analyzed for non-asbestos constituents in accordance with the *Additional Corrective Action Required for Landfarm Soil Analysis from the Former Zonolite Export Plant, 100 Highway 37, Libby, Lincoln County, Montana; Facility ID 27-13196, Release 1729, Work Plan 7108* (MDEQ, 2013).

Soil sample results indicated the presence of petroleum hydrocarbons, although when ranges were compared against their respective Montana Tier 1 Risk Based Screening Levels for Petroleum Releases (MDEQ, 2009), only C11-C22 aromatics slightly exceeded its screening level of 400 mg/kg at a concentration of 424 mg/kg (MWH, 2013a).

Detailed information on the landfarm sampling effort and results are provided in the *Corrective Action Summary Report for the Landfarm Soil Analysis for the Former Zonolite Export Plant, 100 Highway 37, Libby, Lincoln County, Montana; DEQ Facility ID 27-13196, Release 1729, Work Plan 7108* (MWH, 2013a). These soil samples were not collected under the 2007 AOC for the OU3 Study Area RI/FS or under an approved EPA SAP/QAPP and therefore the results will not be carried forward through the remainder of this report.

4.5.4 Geotechnical Test Pit Evaluation (2014) – Sampling Activities

The objective of the test pit sampling effort was to collect additional field data to establish the geotechnical and engineering characteristics, and LAA content of the soils, mined materials, and weathered bedrock along possible creek diversion locations and in the proposed borrow source areas associated with potential water management scenarios for the OU3 Study Area.

Excavation of 27 test pits was completed at locations surrounding and within the KDID and tailings impoundment materials, along potential creek diversions and, within potential construction borrow source areas. Test pits were excavated using an excavator to depths of up to 15 ft. bgs. All test pits were logged by a field geologist to identify and characterize soil type according to the USCS and describe the materials encountered according to interpretations of the type and nature of the deposit. Detailed field logging of the subsurface materials, stratigraphy and encountered obstructions (e.g., tree roots, buried pipes, etc.), as well as observations concerning groundwater infiltration were recorded on field logs during the excavation process. Eighty one (81) grab soil samples were collected for LAA analysis from varying pit depths based upon soil types. If multiple soil types existed within a single pit a single grab sample was collected from each soil type. Composite soil samples of varying volumes were collected for geotechnical analysis (discussed in **Section 4.9.1**). Volumes were based upon geotechnical testing requirements.

Table 4-1 outlines the number of soil samples collected in the Geotechnical Test Pit Evaluation. **Table 4-2** provides the soil sampling locations by station ID, station description, and analyses conducted for soil samples collected in the Geotechnical Test Pit Evaluation. Soil sample locations that were analyzed for LAA are presented on **Figure 4-4a**.

Soil samples from the test pits were collected and analyzed for LAA in accordance with the *Work Plan for Geotechnical Characterization in Support of Creek Diversions at Libby Superfund Site OU3 Revision 2* (MWH, 2014a) (refer to **Section 4.9.1** for additional geotechnical sample information).

LAA soil samples were collected and delivered to the SPF in Troy, Montana. Once the samples were prepared by the SPF, they were delivered to EMSL in Libby, Montana for analysis of LAA by PLM-VE (and PLM-Grav, if a coarse fraction was present).

Detailed information on the Geotechnical Test Pit effort including all associated field documentation, is provided in the *Kootenai Development Impoundment Dam (KDID) Geotechnical and Hydrogeological Investigation Report* which is included as part of this report (MWH, 2015a) and the LAA results are summarized in **Section 5.0** of this report.

4.5.5 Reconnaissance Surveys (2014) – Sampling Activities

Reconnaissance surveys were performed in the OU3 Study Area in June, October, and November 2014. The purpose of this work was to gather additional geological and LAA concentration information in soil and bedrock units to help characterize the stratigraphy, geotechnical engineering parameters, and conditions. The June effort was implemented simultaneously with the geotechnical test pit investigation program as described above and in **Section 4.5.4.** The overall focus of the reconnaissance was LRC, Fleetwood Creek, Carney Creek, Tub Gulch, and in the general vicinity of the KDID, spillway, and potential creek diversion features.

Exclusive to the June survey, four grab soil samples were collected at depths ranging from six to eighteen inches at four locations designated as PT184, PT-185, PT-190, and PT-198 on **Figure 4-4a.**

Table 4-1 outlines the number of soil samples collected in the Reconnaissance Surveys. **Table 4-2** provides the soil sampling locations by station ID, station description, and analyses conducted for soil samples collected in the Reconnaissance Surveys. Soil sample locations that were analyzed for LAA are presented on **Figure 4-4a**.

Reconnaissance activities were conducted in accordance with the *Work Plan for Geotechnical Characterization in Support of Creek Diversions at Libby Superfund Site OU3 Revision 2* (MWH, 2014a). Soil samples were collected during the June effort only and delivered to the SPF in Troy, Montana. Once the samples were prepared by the SPF, they were delivered to EMSL in Libby, Montana for analysis of LAA by PLM-VE (and PLM-Grav, if a coarse fraction was present). The results of the LAA samples are summarized in **Section 5.0** of this report.

Detailed information on the Geotechnical Test Pit effort including all associated field documentation, is provided in the *Test Pit LAA Results and Creek Reconnaissance Report* (MWH, 2016a), and the results are summarized in **Section 5.0** of this report.

4.5.6 Trespasser Activity Based Sampling (2015) – Sampling Activities

The objective of the trespasser activity-based sampling investigation was to assess concentrations of LAA in activity-based air samples during source material disturbance activities in the Former Mine Area. Two trespassing ABS activities were completed (discussed below in **Section 4.8.12**) and road material samples (soil) were collected along the unpaved roads travelled by the ATV riders during the ABS activities. These soil samples were collected because

there were limited or no data available on the nature and extent of LAA in road materials on the Former Mine Area. Thirty seven (37) total grab soil samples were collected along three different ATV routes every 0.25 of a mile within the roadway from a depth of surface to six inches.

Table 4-1 outlines the number of soil samples collected in the Trespasser Activity Based Sampling Program. **Table 4-2** provides the soil sampling locations by station ID, station description, and analyses conducted for soil samples collected in the Trespasser Activity Based Sampling Program. Soil sample locations that were analyzed for LAA are presented on **Figure 4-4a**.

Samples were collected in accordance with the *Sampling and Analysis Plan / Quality Assurance Project Plan: Operable Unit 3 Study Area, Libby Asbestos Superfund Site Trespasser Activity-Based Sampling* (EPA, 2015c).

Soil samples were delivered to the SPF in Troy, Montana. Once the samples were prepared by the SPF, they were delivered to EMSL in Libby, Montana for analysis of LAA by PLM-VE (and PLM-Grav, if a coarse fraction was present).

Detailed information on the Trespasser Activity Based Sampling, including all associated field documentation, is provided in the *2015 FSSR* (MWH, 2016b) and the results are summarized in **Section 5.0** of this report.

4.6 FOREST SOIL, DUFF MATERIAL, TREE BARK, AND ASH FROM THE FORESTED AREAS

The Phase I sampling program included the collection of forest soil, duff material (i.e., leaf litter, pine needles, organic debris), and tree bark from the forested area surrounding the mine. The samples were collected in October 2007 and analyzed for LAA. In the fall of 2011, a subset of the forest soil samples collected during Phase I was subsequently analyzed for metals/metalloids. Additional sampling events were conducted between 2012 and 2015, which included the collection of soil, duff, ash, and tree bark. **Table 4-1** outlines the number samples collected for forest soil, duff material, tree bark, and ash by sampling phase/event. **Table 4-2** provides the forest soil, duff material, tree bark, and ash sampling locations by station ID, description, sampling phase/event, and analyses conducted. Forest soil, duff material, tree bark, and ash sample locations that were analyzed for LAA are presented on **Figure 4-5a.** Forest soil samples that were analyzed for non-asbestos constituents are presented on **Figure 4-4b.** Detailed results for LAA and for non-asbestos constituents (limited forest soil samples only) detected in forest soil, duff material, tree bark, and ash samples collected throughout the OU3 Study Area are provided and discussed in **Section 5.0.**

4.6.1 Phase I (2007) – Sampling Activities

The objective of the Phase I forest sampling effort was to establish the potential extent and spatial pattern of releases of airborne LAA from the mine operations that could become entrained into the surrounding environment. To facilitate an analysis of a spatial-pattern from a selected point source, samples were collected along a number of transects that radiated away from the center point of the Former Mine Area (presented as Mine Center on **Figures 1-3** and **4-5a**), with more and longer transects on the predominant downwind direction (northeast), under the assumption that LAA from the point source (the mine) would be higher in these areas. At each location one Douglas fir tree (at least 8 inches in diameter) was selected for tree bark analysis. Preference

was given to trees having rough bark since it was expected that rough bark would tend to capture and retain airborne LAA fibers on the bark surface more efficiently. For each tree, a tree bark sample was collected at a height of about four to five ft. above ground from the side of the tree facing the Former Mine Area using a 2-inch diameter hole saw. Samples were not collected from other locations on the tree. In addition, for about 10% of the selected trees, an increment boring device was used to collect a core sample for tree-ring analysis to establish the tree age. At each location, one 5-point composite soil sample was collected from ground surface to a depth of two inches and approximately equally spaced sub-locations around the perimeter of a circle with a radius of about five ft., centered on the tree that was selected for bark analysis. At each soil collection sub-location, the duff material that was overlying the surface soil also was collected to determine if this organic debris layer contained LAA fibers.

A total of 74 tree bark, 12 tree core, 74 forest soil, and 73 duff material samples were collected and analyzed for LAA. **Table 4-1** outlines the number of tree bark, tree core, forest soil, and duff material samples collected in Phase I. **Table 4-2** provides the tree bark, tree core, forest soil, and duff material sampling locations by station ID, station description, and analyses conducted for tree bark, tree core, forest soil, and duff material samples collected in Phase I. Tree bark, tree core, forest soil, and duff material sample locations that were analyzed for LAA are presented on **Figure 4-5a**.

Samples were collected in accordance with the *Phase I Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site* (EPA, 2007b).

The tree bark and duff material samples were sent to EMSL in Libby, Montana, Westmont, New Jersey, and Beltsville, Maryland for preparation and analysis for LAA in accordance with EPA SOP TREE-LIBBY-OU3 and EPA SOP DUFF MATERIAL-LIBBY-OU3, respectively. In brief, the samples were dried, reduced to ash, weighed, and hand-mixed. The total mass of each sample was prepared. An aliquot of the resulting ash was treated with acid, suspended in water, and filtered onto a 47mm mixed cellulose ester filter with 0.4-µm pore size. This filter was prepared and analyzed by TEM in accordance with ISO 10312:1995(E) (ISO 1995) and with all applicable EPA Libby Site-specific laboratory modifications. Soil samples collected in the field for LAA analysis were sent to the CDM Smith CSF in Denver, Colorado for preparation. After preparation, samples were sent to EMSL in Libby, Montana for analysis of LAA by PLM-VE (and PLM-Grav, if a coarse fraction was present).

Cores were sent to the Tree-Ring Laboratory at the University of Arizona for the estimation of tree age. The twelve trees selected for this analysis ranged in age from 29 to 100 years old (average age was 69 years). The oldest trees sampled were in SL15 (about 5 miles from the Former Mine Area center, 30 degrees counter clock-wise from the approximate primary downwind direction). A comparison of the tree diameter measured in the field relative to the tree age (as determined by the age cores) was made. Based on these comparisons, the age of coniferous trees in this area cannot be accurately predicted utilizing measured tree diameter only (CDM Smith, 2016).

In the fall of 2011, the EPA determined that a subset of the forest soil samples collected as part of the Phase I investigation should be subsequently analyzed for metals/metalloids. The purpose of this effort was to provide site-specific data on metal concentrations in soils that were thought to be representative of reference conditions (i.e., not impacted by releases from mining activities) based on geographic distance from the mine. A total of 12 samples were selected for metals analysis. Soil samples were selected by the EPA from the furthest two sampling locations from

the distal ends of each of six transects, three downwind transects, and three cross-wind/upwind transects. All samples were analyzed for metals/metalloids by ELI.

Table 4-1 outlines the number forest soil samples collected for non-asbestos constituents in Phase I. **Table 4-2** provides the forest soil sampling locations by station ID, station description, and analyses conducted for forest non-asbestos constituent soil samples collected in Phase I. Forest soil sample locations that were analyzed for non-asbestos constituents are presented on **Figure 4-4b**.

Detailed information on the EPA directed Phase I field sampling effort, including all associated field documentation, is provided in the *Phase I FSSR* (MWH, 2007) and the results are summarized in **Section 5.0** of this report.

4.6.2 Phase IV, Part A (2010) – Sampling Activities

The Phase IV Part A sampling program focused on the collection of ABS data in an attempt to evaluate potential LAA exposures to recreational visitors along the OU3 Study Area streams and ponds, residential wood harvesters, USFS workers, and fire fighters in the forested area (under staged fire-fighting conditions). In addition, the Phase IV Part A SAP included a plan for the collection of tree bark samples from each of two slash piles prior to the simulated wildfire ABS activities that were to be performed at the slash piles. Four samples were collected and analyzed for LAA to establish the levels of LAA in each pile (utilizing tree bark sample results) prior to burning. A total of eight tree bark samples were collected from each slash pile, and two samples from each pile were analyzed for LAA the remaining samples were archived. As stated in the *DSR* (CDM Smith, 2016), it was subsequently determined that the simulated wildfire ABS activities would not be performed at the slash piles.

Table 4-1 outlines the number tree bark samples collected in Phase IV Part A. **Table 4-2** provides the tree bark sampling locations by station ID, station description, and analyses conducted for tree bark collected in Phase IV Part A. Tree bark sample locations that were analyzed for LAA are presented on **Figure 4-5a**.

4.6.3 Commercial Logging (2012) – Sampling Activities

The objective of the 2012 Commercial Logging investigation was to collect air samples during commercial logging activities to provide site-specific data on potential exposures to LAA for workers involved in commercial logging activities in the forest near the mine site. LAA concentrations at actual logging locations further from the mine site were expected to be significantly less than those at the simulation site, and thus pose a lower risk. As part of this samples of tree bark and duff material within the study area also were collected and analyzed for LAA. The site selected was in the area with the highest -measured concentrations of LAA in bark and duff material. Sampling efforts were conducted in September 2012.

A total of five (5) tree bark and five (5) duff samples were collected from locations that were considered spatially representative of the study area. For tree bark, each sample was a composite consisting of five cores, collected by cutting a circle of bark with a hole saw, from five different trees. For duff material, each sample was a five multi-point composite collected near each of the trees selected for tree bark sampling.

Table 4-1 outlines the number tree bark and duff material samples collected in the 2012 Commercial Logging Program. **Table 4-2** provides the tree bark and duff material sampling

locations by station ID, station description, and analyses conducted for tree bark and duff material collected in the 2012 Commercial Logging Program. Tree bark and duff material sample locations that were analyzed for LAA are presented on **Figure 4-5a**.

Samples were collected in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan Operable Unit 3, Libby Asbestos Superfund Site 2012 Commercial Logging Activity-Based Sampling* (EPA, 2012g).

All tree bark and duff material samples were collected and sent to EMSL laboratory in Cinnaminson, New Jersey for preparation and analysis for LAA in accordance with SOP TREE-LIBBY-OU3 and SOP DUFF MATERIAL-LIBBY-OU3, respectively. In brief, samples were dried, ashed, weighed, and hand-mixed.

Samples of bark and duff material were first ashed at high temperature to remove organic matter. A portion of the ashed residue was suspended in acid to dissolve non-asbestos mineral salts, and then diluted in water for filtration through a filter. Filters were prepared in triplicate for each tree bark and duff material sample, with each filter being prepared using a new aliquot of ash and analyzed in parallel. One analysis was performed in 2012 and two additional replicate analyses were performed in 2013 for each tree bark and duff sample. Filters were analyzed for LAA using TEM in accordance with ISO 10312:1995(E) (ISO 1995) with all applicable Libby Site-specific laboratory modifications.

Detailed information on the 2012 Commercial Logging field sampling effort, including all associated field documentation, is provided in the *2012 Phase V Remedial Investigation FSSR* (MWH, 2013c) and the results are summarized in **Section 5.0** of this report.

4.6.4 Nature and Extent Forest (2012) – Sampling Activities

The objective of the 2012 Nature and Extent Forest study was to collect data on LAA concentrations in tree bark and duff material that can be used to evaluate the nature and extent of LAA levels in the forested areas outside of the OU3 Study Area. A total of 51 locations were sampled from within a two-mile buffer extending beyond the NPL boundary. Sampling locations were placed in areas accessible by USFS roads with adequate tree cover. To the extent possible, the precise sampling locations were placed in open areas that were not likely to have been substantially shielded from airborne deposition of asbestos by local features.

Tree bark and duff samples were collected at each of the 51 locations. Tree bark composite samples were collected using a hole saw and chisel. One sample from three different trees was collected and composited into a single sample. Additionally, one duff composite sample was collected near each of the three trees sampled for tree bark.

Table 4-1 outlines the number tree bark and duff material samples collected in the 2012 Nature and Extent Forest Program. **Table 4-2** provides the tree bark and duff material sampling locations by station ID, station description, and analyses conducted for tree bark and duff material collected in the 2012 Nature and Extent Forest Program. Tree bark and duff material sample locations that were analyzed for LAA are presented on **Figure 4-5a**.

Samples were collected in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan: Nature and Extent of LA Contamination in the Forest* (EPA, 2012h).

Tree bark and duff samples were sent to EMSL-Libby, EMSL-Cinnaminson, Hygeia, or RESI for preparation and analysis for LAA in accordance with SOP EPA-LIBBY-2012-12. Samples were dried, ashed, weighed, and hand-mixed. Samples of bark and duff were first ashed at high temperature to remove organic matter. A portion of the ashed residue was suspended in acid to dissolve non-asbestos mineral salts, and then diluted in water for filtration through a filter. All tree bark and duff filters were analyzed for LAA using TEM in basic accordance with ISO 10312:1995(E) (ISO 1995) with all applicable Libby Site-specific laboratory modifications.

Detailed information on the 2012 Nature and Extent Forest field sampling effort, including all associated field documentation, is provided in the *Data Summary Report: Nature and Extent of LA Contamination in the Forest* (EPA, 2013c) and the results are summarized in **Section 5.0** of this report.

4.6.5 Simulated Open Burning of Duff Material (2012) – Sampling Activities

The objective of the Simulated Open Burning of Duff Material investigation was to provide data on LAA concentrations in air that firefighters could potentially be exposed to in the event of a forest fire, assuming that LAA may potentially be released into the air, via smoke, during the burning of duff and tree bark. A series of laboratory-scale experiments were performed at the EPA's Open Burn Test Facility (OBTF), located at the EPA facilities in Research Triangle Park, NC (EPA, 2012i). These experiments involved collecting measurements of LAA in smoke released from the burning of LAA-impacted duff collected from a location approximately one mile downwind of the Former Mine Area in a series of controlled burns in the OBTF. The experiments were performed with the intent to simulate the temperatures and other conditions of a wildfire as much as possible in a laboratory setting.

The burning occurred in an enclosed shed (also known as a "Burn Chamber" or "Burn Hut"). There were two distinct experimental conditions: 1) a "High Temperature" condition intended to simulate the rapid combustion that occurs during a wildfire; and 2) a "Low Temperature" condition intended to simulate the smoldering combustion that occurs after the initial fire associated with a wildfire that has subsided. For the High Temperature tests, the Burn Chamber consisted of a grate with an up-fired propane burner to provide continuous high temperatures to a supply of duff that was replenished periodically. For the "Low Temperature" tests, the Burn Chamber consisted of a grate with a small propane torch (a different burner than the one used in the High Temperature tests) to sustain the burning of a pile of duff that was periodically replenished.

Duff material was fed by gravity into the Burn Chamber and was replenished during the burn by the addition of new duff material through a feed chute. Air was provided by a fan that blew measured quantities of air into the Burn Hut. Smoke from the burning material traveled through an exhaust flue where measurements were collected for combustion gases (O_2, CO, CO_2), total filterable particulate matter (PM), PM less than or equal to 2.5 µm ($PM_{2.5}$), and LAA fibers (airborne, residual ash, and wipe samples from the walls of the OBTF). It should be noted that at the time of the investigation no validated sampling methods were available for measurement of LAA from combustion sources (EPA, 2012i). Methods existed for measurement of asbestos in ambient air, and methods existed for measurement of PM in stack gases. Therefore, to quantify the LAA fibers in the smoke from the exhaust duct, multiple hybrids of ambient asbestos methods coupled with stack PM measurement methods were adapted and used so that acceptable samples could be acquired and analyzed in spite of the lack of validated sampling methods (EPA, 2012i). LAA in burn chamber smoke was sampled using two different techniques: 1) the Mixed Cellulose Ester (MCE) Filter Method (the standard for ambient measurement of asbestos); and 2) the Impinger Method (a variant on stack sampling methods). For details pertaining to the MCE

and Impinger methods refer to the *Investigation for Operable Unit 3 Libby Asbestos Superfund Site; Quality Assurance Project Plan; Estimation of Asbestos Levels in Smoke Using a Burn Chamber* (EPA, 2011b).

Before it was placed in the Burn Chamber, the duff starting material was analyzed for LAA as well as characterized as fuel using proximate and ultimate analyses (EPA, 2012i). These measurements were combined with measurements of the mass of duff material burned and various flow rates through the OBTF to generate an estimate of emission factors of fibers per PM (LAA fibers per mass of duff material burned divided by $PM_{2.5}$ in terms of mass emitted per mass of duff burned).

Table 4-1 outlines the number of duff material, smoke, and ash samples collected in the Simulated Open Burning of Duff Material Program. **Table 4-2** provides the duff material, smoke, and ash sample information by station ID, station description, and analyses conducted for duff material and ash collected in the Simulated Open Burning of Duff Material.

Samples were collected in accordance with the *Investigation for Operable Unit 3 Libby Asbestos Superfund Site; Quality Assurance Project Plan; Estimation of Asbestos Levels in Smoke Using a Burn Chamber* (EPA, 2011b).

All MCE filters, collected water samples from impinger sampling, and ash were shipped to EMSL Analytical for estimation of LAA by TEM.

Detailed information on the 2012 Simulated Open Burning of Duff Material Program, including all associated documentation, is provided in the *Emissions of Amphibole Asbestos from the Simulated Open Burning of Duff from Libby, MT* (EPA, 2012i) and the results are summarized in **Section 5.0** of this report.

4.6.6 Wood-burning Stove Ash Removal (2012) – Sampling Activities

The objective of the Wood-burning Stove Ash Removal investigation was to evaluate the potential exposures to individuals from exposure to LAA in air while removing ash from a wood-burning stove. The tasks performed as part of this investigation included the burning of locally-collected wood in a wood-burning stove and the collection of personal air samples under an ABS sampling scenario of a person emptying the ash from the stove. Ash was removed using a long-handled metal shovel and placed into a metal ash bucket. A soft-bristled brush was then used to sweep up and gather any additional ash material from the stove. Tree bark and ash samples were collected prior to the stove-emptying activity to provide information on LAA concentrations in materials selected for the burn. Perimeter air monitoring also was conducted during the wood burning and stove emptying events to verify that ABS activities did not result in releases to air outside of the ABS area.

Firewood was collected from dead trees at three locations at varying distances from the Former Mine Area: near the Former Mine Area (approximately one mile downwind of the Former Mine Area), near Flower Creek (approximately two miles south of Libby and nine miles upwind of the Former Mine Area), and near Bear Creek (approximately 10 miles south of Libby and outside the current NPL boundary)[5]. Prior to burning the firewood, a hole saw and chisel were used to collect five circular bark cores from each of the firewood samples, and were composited into a single

[5] Although the locations evaluated near Flower Creek and near Bear Creek are not within the OU3 Study Area, they are retained in this RI for the purposes of comparison to the location near the Former Mine Area.

sample for analysis of LAA by TEM. The collected firewood from each location was then burned in a separate woodstove for six hours (tree bark was not removed prior to burning). One sample of ash material was collected from each of the three separate stoves prior to performing three separate ABS events.

Table 4-1 outlines the number tree bark and ash samples collected in the 2012 Wood-burning Stove Ash Removal. **Table 4-2** provides the tree bark and ash sampling locations by station ID, station description, and analyses conducted for tree bark and ash collected in the 2012 Wood-burning Stove Ash Removal. Firewood collection locations are presented on **Figure 4-5b**.

Samples were collected in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan: Wood-Burning Stove Ash Removal Activity Based Sampling, Libby Asbestos Site, Operable Unit 4, Libby, Montana. Revision 0* (CDM Smith, 2012).

A total of nine tree bark samples were collected (one tree bark sample from three ABS events and three tree collection locations) and then prepared and analyzed in basic accordance with the procedures specified in SOP EPA-LIBBY-2012-12, *Sampling and Analysis of Tree Bark for Asbestos*. In brief, each sample was dried and ashed, and the resulting ash residue was acidified, suspended in water, and filtered. Three replicate filters were created for each tree bark sample using equal aliquots of the ash residue. Each replicate filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E) with all applicable Libby Site-specific laboratory modifications.

A total of nine ash samples were collected (one ash sample from three ABS events and three tree collection locations) and then prepared and analyzed using procedures similar to those specified in SOP EPA-LIBBY-2012-11, *Sampling and Analysis of Duff for Asbestos*. In brief, an aliquot of the ash material was acidified, suspended in water, and filtered. Three replicate filters were created for each ash sample using additional aliquots of the ash residue. Each filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E) with all applicable Libby Site-specific laboratory modifications.

Detailed information on the 2012 Wood-burning Stove Ash Removal sampling effort, including associated field documentation, can be found in the *Data Summary Report: Wood-burning Stove Ash Removal Activity-Based Sampling* (CDM Smith, 2013a). The results of the investigation are summarized in **Section 5.0** of this report.

4.6.7 Souse Gulch (2013) – Sampling Activities

At the request of the USACE, the U.S. Public Health Service (USPHS) and the Federal Occupational Health Service (FOH) conducted environmental duff material/bark sampling and analysis and activity based air sampling in May 2013 near the USACE Libby Dam based on USACE plans to renovate areas of the Souse Gulch Campgrounds. Renovations will include excavation of soils, disturbance of forest vegetation (including timber, duff material, and brush), and removal of several trees. The USACE is concerned that workers may be exposed to elevated levels of LAA when conducting these activities. To clarify potential exposure from cutting down trees and disturbing soils, the USACE tasked FOH with collecting representative core bark and duff material samples from trees and soils within the areas of the proposed renovations. In a similar study conducted in August 2012, NIOSH found no exposure resulting from ABS sampling during the numerous forest management activities including fire line construction (USDHHS, 2014). In addition, the USACE is responsible for keeping roadways and driving trails in and around the Souse Gulch Campgrounds and Libby Dam areas clean. After each winter,

sand used to coat the roadways for safer driving after ice and snow storms and other debris that collects on the roadways, including pine needles, are removed using three types of street sweepers. FOH was tasked to collect tree bark, duff material samples, and personal air samples on workers driving the street sweepers and workers driving water trucks used to wet/dampen sand and debris prior to being picked up/swept by the street sweepers. The purpose of the collection of these samples was to determine potential exposures and not to utilize the data in conjunction with the ABS samples collected during the same investigation (USACE, 2013). The personal air samples are discussed in **Section 4.8.6**.

Tree bark and duff material samples were collected within USACE property in the Souse Gulch Campgrounds. Six trees were tagged with red flagging tape by the USACE that met the sampling criteria. Bark core samples were collected only from the side of the tree facing toward the mine (northwest). Duff material samples were collected on the ground below these trees from the same side. A total of six (6) tree bark samples and six (6) duff material samples were collected with one each of tree bark and duff material samples being duplicates for QA/QC purposes.

Table 4-1 outlines the number tree bark and duff material samples collected in the 2013 Souse Gulch Program. **Table 4-2** provides the tree bark and duff material sampling locations by station ID, station description, and analyses conducted for tree bark and duff material collected in the 2013 Souse Gulch Program. Tree bark and duff material sample locations that were analyzed for LAA are presented on **Figure 4-5a**.

All samples were shipped to Reservoirs Environmental under chain-of-custody protocols as described in the SOP. Samples were prepared and analyzed by TEM by Reservoirs Environmental as described in the SOP following ISO TEM Method 10312. Tree bark and duff material were collected and analyzed in accordance with the SOP provided by the USACE, *Asbestos Tree Bark and Duff Material Sampling and Analysis Plan Libby Dam Libby, Montana Dated April 2013*. Samples were analyzed by Reservoirs Environmental Inc. located in Denver, Colorado. Reservoirs Environmental is accredited by the NVLAP for LAA analysis by TEM/PLM.

Detailed information on the 2013 Souse Gulch sampling effort, including all sampling methodology and associated field documentation, is provided in the *Environmental Duff Material/Bark Sampling & Analysis with Activity Based Air Sampling Investigation* (USACE, 2013) and the results are summarized in **Section 5.0** of this report.

4.6.8 Souse Gulch Wildfire Monitoring (2013) – Sampling Activities

The objective of the Souse Gulch Wildfire Monitoring was to measure LAA concentrations in air during a natural wildfire in the OU3 Study Area in order to estimate potential exposure of LAA from wildfires in the OU3 Study Area. Trial burn experiments in wood stoves (Ward *et al.,* 2009) and in test burn chambers (EPA, 2012i) reported that the majority of LAA fibers are retained in the ash when wood and duff materials are burned under experimental conditions. Therefore, a secondary goal of this study was to measure LAA concentrations in ash following a wildfire in the OU3 Study Area that may be used to provide information on the potential for subsequent exposures to human or ecological receptors.

In the event of a natural wildfire in the OU3 Study Area, the plan (EPA, 2015d) included collecting opportunistic air samples, both at stationary monitors throughout the Libby community and near the wildfire (to evaluate exposures to firefighters). To date, air samples have only been collected during one natural wildfire event. In late July 2013, a small (1.5 acre) wildfire occurred in the Souse Gulch day-use recreation area on Lake Koocanusa behind Libby Dam (approximately 2.5

miles southeast from the mine). During this fire, air samples were collected to provide data on LAA exposures of responding firefighters (both to the ground crews and the aircraft support pilot) and downwind LAA concentrations in air during the fire (discussed below in **Section 4.8.7**).

In addition, ash material was collected from the burn area and placed into a 5-gallon bucket. Detailed information on the ash sample collection and analysis are provided on the field modification approval form LFM-OU3-01 (EPA, 2015d). In brief, the Troy SPF utilized a riffle splitter to remove three ash samples for TEM analysis from the bucket. Each ash sample was analyzed by TEM in triplicate.

Table 4-1 outlines the number ash samples collected in the 2013 Souse Gulch Wildfire Monitoring. **Table 4-2** provides the ash sample location by station ID, station description, and analyses conducted for ash collected in the 2013 Souse Gulch Wildfire Monitoring. The ash sample location that was analyzed for LAA is presented on **Figure 4-5a**.

Samples were collected in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan, Operable Unit 3, Libby Asbestos Superfund Site, Wildfire Contingency Monitoring Plan, Revision 3* (EPA, 2015d)

Detailed information on the Souse Gulch sampling can be found in the *DSR* (CDM Smith, 2016). The results of the Souse Gulch wildfire sampling are summarized in **Section 5.0** of this report.

4.6.9 Commercial Logging (2014) – Sampling Activities

The objective of the 2014 Commercial Logging investigation was to evaluate the potential exposures to commercial logging workers in areas with lower LAA concentrations in tree bark and duff material. As part of this investigation, ABS air samples were collected during commercial logging activities in an area of the OU3 Study Area known to have lower LAA concentrations in tree bark and duff material than the commercial logging area evaluated in 2012, and these tree bark and duff material samples were analyzed for LAA. Sampling efforts were conducted in August and September of 2014.

Prior to initiation of ABS activities, samples of tree bark and duff material within the study area were collected and analyzed for LAA. A total of five (5) tree bark and five (5) duff material samples were collected from locations that were spatially representative of the study area. Each tree bark sample was a composite consisting of five cores, collected by cutting a circle of bark with a hole saw, from five different trees. Tree bark samples were collected in accordance with Libby Site-specific SOP EPA-LIBBY-2012-12. For duff material, each sample was a five-point composite collected from a five foot radius surrounding the tree that was selected for bark sampling. Samples of duff material were collected in accordance with Libby Site-specific SOP EPA-LIBBY-2012-11, with modifications as specified in the governing QAPP. In brief, at each specified sampling location, fresh or partially decayed organic debris (e.g., twigs, leaves, pine needles) was collected by hand from the soil surface, taking care that the top layer of soil beneath the organic debris was not included in the duff material sample.

Table 4-1 outlines the number tree bark and duff material samples collected in the 2014 Commercial Logging Program. **Table 4-2** provides the tree bark and duff material sampling locations by station ID, station description, and analyses conducted for tree bark and duff material collected in the 2014 Commercial Logging Program. Tree bark and duff material sample locations that were analyzed for LAA are presented on **Figure 4-5a**.

Samples were collected in accordance with the *Quality Assurance Project Plan: Commercial Logging Activity-Based Sampling Libby Asbestos Superfund Site Revision 0* (USACE, 2014a).

Duff material samples were prepared and analyzed in accordance with the procedures specified in SOP EPA-LIBBY-2012-11, *Sampling and Analysis of Duff Material for Asbestos*. In brief, at the analytical laboratory, each sample was dried, ashed, and an aliquot of the resulting ash residue was acidified, suspended in water, and filtered. The resulting filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E) with all applicable Libby Site-specific laboratory modifications. Remaining ash material was archived for possible future analysis.

All tree bark samples were sent for preparation and analysis for LAA in accordance with SOP EPA-LIBBY-2012-12, *Sampling and Analysis of Tree Bark for Asbestos*, with the following modification: only an aliquot of the resulting ash residue (rather than the total mass) was filtered. In brief, each sample was dried and ashed, and an aliquot of the resulting ash residue was acidified, suspended in water, and filtered. The filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E) with all applicable Libby Site-specific laboratory modifications. Remaining ash material was archived for possible future analysis.

Detailed information on the 2014 Commercial Logging field sampling effort, including associated field documentation, can be found in the *2014 Commercial Logging Activity-based Sampling* (EPA, 2015e). The results of the investigation are summarized in **Section 5.0** of this report.

4.6.10 Nature and Extent Forest ABS (2014) – Sampling Activities

The objective of the 2014 Nature and Extent Forest investigation was to measure LAA concentrations in outdoor ABS air samples from locations along the NPL boundary in an effort to estimate potential exposures and risks to populations that may be exposed to LAA in these forested areas. These risk estimates were used by the EPA to inform decisions on the boundaries of the nature and extent of LAA impact in the forest. Following ABS air sample collection, one 30-point soil sample was collected from each of the ten (10) sampling locations. However, soil samples only were collected during the first of the three sampling events scheduled for each sampling location. All soil samples collected for this study were archived for potential future analysis as directed by the EPA.

Visible Vermiculite Estimation. Visual estimation of the amount of vermiculite in each of the 30 aliquot sub-locations was performed in accordance with Libby Site-specific SOP CDM Smith-LIBBY-06, *Semi-Quantitative Visual Estimation of Vermiculite in Soils* with project modifications detailed in the QAPP prepared for Nature and Extent – Forest Activity-Based Sampling (USACE, 2014b).

Soil Moisture Measurement. Prior to conducting ABS activities, soil moisture was measured in the field using a portable soil moisture meter from a minimum of 10 locations along the fire line excavated for the ABS sampling between 0 and 3 inches below ground surface.

Table 4-1 outlines the number forest soil samples collected in the 2014 Nature and Extent Forest ABS Program. These samples are archived and have not been analyzed therefore they are not included on **Table 4-2** or **Figure 4-6**.

Samples were collected in accordance with the *Quality Assurance Project Plan: Nature and Extent – Forest Activity-Based Sampling Libby Asbestos Superfund Site Revision 1* (USACE, 2014b).

Detailed information on the 2014 Nature and Extent field sampling effort, including all associated field documentation can be found in the *Nature and Extent Forest Activity-based Sampling* (EPA, 2015f). The results of the investigation are summarized in **Section 5.0** of this report.

4.6.11 Slash Pile Burn (2015) – Sampling Activities

The objective of the Slash Pile Burn investigation, which was performed in May 2015, was to provide sufficient data on LAA concentrations in air to allow the EPA to complete an exposure assessment for forest workers conducting slash pile burning activities in the forest near the mine. Slash piles are the accumulation and piling up of limbs, tops, and miscellaneous residue left by logging and various forest management activities, such as thinning, pruning and timber harvesting, which occur in forested areas of the OU3 Study Area. The EPA used the exposure assessment to evaluate potential risks to forest workers. The risk assessment will be used to support decisions about whether or not response actions are needed to protect forest workers from unacceptable risks during a slash pile burn. While there have been several ABS studies conducted at the OU3 Study Area to assess potential exposures under a variety of exposure conditions, there were no prior ABS data to evaluate exposures during the burning of slash piles.

The study performed a controlled prescribed slash pile burn and collected samples to measure LAA concentrations in the air that resulted from the fire. The constructed slash pile was approximately six ft. high and 15 ft. wide. Prior to the burn, tree bark, duff material, and forest soil samples were collected to represent the materials included in the slash pile. Three (3) tree bark samples were collected within the slash pile burn activity area and consisted of three-core composite samples that were collected from intact bark from trees selected for the slash burn pile. Five (5) duff samples were collected from within the selected area for the slash pile burn activities and consisted of five point composites. Three (3) pre-burn and three (3) post-burn forest soil samples were collected within the slash pile burn activity area from a depth of zero to six inches below ground surface and consisted of 30-point composite samples. Finally, one (1) ash sample was collected from the burn area prior to conducting mop-up activities to provide measured data on LAA levels in the ash following the burn. The ash sample was collected within the slash pile burn activity area from a depth of zero to one inches below ground surface and consisted of a 30-point composite.

Forest Soil composite samples were collected pre-burn and post-burn and were prepared in accordance with 16-ASB-06.02 at the SPF in Troy, MT. Samples were scrutinized for organic matter to avoid igniting during the drying process. One aliquot of the fine-ground sample was analyzed for asbestos by PLM-VE in accordance with SOP SRC-LIBBY-03, as modified by the most recent version of Libby laboratory modification LB-000073. If there was a coarse fraction of the sample, it was analyzed for asbestos by PLM-Grav in accordance with SOP SRCLIBBY-01.

Tree bark samples were prepared and analyzed in accordance with the procedures specified in SOP EPA-LIBBY-2012-12, with the following project modifications: only one 0.25-gram aliquot of the resulting ash residue (rather than the total mass) was filtered. In brief, the three cores for each sample were combined, dried, and ashed, and an aliquot of the resulting ash residue was acidified, suspended in water, and filtered. The resulting filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E). Any remaining ash material was archived for possible future analysis.

Duff material samples were prepared and analyzed in accordance with the procedures specified in SOP EPA-LIBBY-2012-11. Each sample was dried and ashed, and an aliquot of the resulting ash residue was acidified, suspended in water, and filtered. The resulting filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E). Any remaining ash material was archived for possible future analysis.

Ash samples were prepared and analyzed in accordance with the procedures specified in SOP EPA-LIBBY-2012-11. An aliquot of the ash material was acidified, suspended in water, and filtered. A total of three replicate filters were created and analyzed for each ash sample using additional aliquots of the ash residue. Each filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E) with all applicable Libby Site-specific laboratory modifications.

Table 4-1 outlines the number forest soil, tree bark, duff material, and ash samples collected in the Slash Pile Burn Program. **Table 4-2** provides the forest soil, tree bark, duff material, and ash sampling locations by station ID, station description, and analyses conducted for forest soil, tree bark, duff material, and ash collected in the Slash Pile Burn Program. Forest soil, tree bark, duff material, and ash sample locations are presented on **Figure 4-5a**.

Samples were collected in accordance with the *Slash Pile Burn Activity Based Sampling Rev. 0 Quality Assurance Project Plan* (USACE, 20015a).

Prior to analysis, all forest soil samples were prepared at the SPF in Troy, MT. Each sample was split into two approximately equal portions: 1- archive; 2-PLM aliquot. The archive aliquot was stored in accordance with SOP 16-ASB-06.02. The PLM aliquot was prepared using SOP 16-ASB-06.02. In brief, the PLM aliquot was sieved into coarse (> ¼ -inch) and fine fractions. The fine fraction was ground to reduce particles to a diameter of 250-µm or less; this fine-ground portion was then split into four aliquots. One aliquot of the fine-ground sample was analyzed for asbestos by PLM-VE in accordance with SOP SRC-LIBBY-03, as modified by the most recent version of Libby laboratory modification LB-000073. If there was a coarse fraction of the sample, it was analyzed for asbestos by PLM-Grav in accordance with SOP SRCLIBBY- 01.

Detailed information on the 2015 slash pile burn investigation sampling effort, including all associated field documentation, is provided in the *2015 FSSR* (MWH, 2016b). The results of the investigation are summarized in **Section 5.0** of this report.

4.6.12 Low-Intensity Prescribed Understory Burn (2015) – Sampling Activities

The objective of the Low-Intensity Prescribed Understory Burn investigation, which was performed in May and June 2015, was to provide additional data on LAA concentrations in air to allow the EPA to complete an exposure assessment for firefighters during the initial attack on a low-intensity, small scale wildfire in the forest near the Former Mine Area. The EPA used the exposure assessment to evaluate potential risks to responding firefighters. The risk assessment will be included in the RI/FS process for decision-making and alternatives analysis for the OU3 Study Area and will be used to support future decisions about whether or not response actions are needed to protect firefighters from unacceptable risks during a low intensity, small-scale fire.

The study performed a small-scale, low-intensity controlled prescribed understory burn and collected samples to measure LAA concentrations in the air that result from the fire and associated firefighter disturbance activities. The understory is defined as the shrubs and plants growing beneath the main canopy of a forest. An area approximately 0.1 acres in size and triangular in

shape was constructed for the understory burn activities. Prior to the burn, soil, duff material, and tree bark samples were collected to represent the materials burned. Four (4) tree bark samples were collected within the understory burn activity area and consisted of two-core composite samples from two trees and one core sample from a third tree. Five (5) duff samples were collected from within the selected area for the slash pile burn activities and consisted of five point composites. Three (3) pre-burn and three (3) post-burn forest soil samples were collected within the slash pile burn activity area from a depth of zero to six inches below ground surface and consisted of 30-point composite samples. Finally, one (1) ash sample was collected from the burn area prior to conducting mop-up activities to provide measured data on LAA levels in the ash following the burn. The ash sample was collected within the understory burn activity area from a depth of zero to one inches below ground surface and consisted of a 30-point composite.

Soil, tree bark, duff material, and ash sample collection and analysis methods for the understory burn were the same as described above in **Section 4.6.11** with the exception of the bark sample collection locations. The bark samples collected as part of the low-intensity controlled prescribed understory burn were collected from a location on the tree approximately two ft. from the ground surface.

Table 4-1 outlines the number forest soil, tree bark, duff material, and ash samples collected in the Understory Burn Program. **Table 4-2** provides the forest soil, tree bark, duff material, and ash sampling locations by station ID, station description, and analyses conducted for forest soil, tree bark, duff material, and ash collected in the Understory Burn Program. Forest soil, tree bark, duff material, and ash sample locations are presented on **Figure 4-5a**.

Samples were collected in accordance with the *Low-Intensity Prescribed Understory Burn Activity -Based Sampling Rev. 0 Quality Assurance Project Plan* (USACE, 2015b).

Detailed information on the 2015 understory burn investigation field sampling effort, including all associated field documentation, is provided in the *2015 FSSR* (MWH, 2016b). The results of the investigation are summarized in **Section 5.0** of this report.

4.6.13 Canoe Gulch and Alexander Ridge Wildfire Monitoring (2015) – Sampling Activities

In August of 2015, several small-scale wildfires occurred within the OU3 Study Area that were extinguished before air monitoring could be initiated. However, samples of soil and duff were collected to evaluate post-fire LAA concentrations following two of the natural wildfires that occurred within the OU3 Study Area. . The two wildfires that occurred within the OU3 Study Area were the Canoe Gulch Fire (Libby Superfund Fire #12 [LSF-12]) and the Alexander Ridge Fire (LSF-13). Following fire-fighting activities, USFS personnel cleaned fire-fighting equipment near the forest fires within the OU3 Study Area and designated these equipment cleaning areas as “decontamination areas” (refer to **Figure 4-5b** identifying fire locations and equipment “decontamination areas”). Soil samples were collected from the decontamination areas, areas near the decontamination areas considered un-impacted, an access road, and a burn area. Duff material samples were collected from the fire sites, the personnel and equipment decontamination areas, and areas near the decontamination areas that were considered un-impacted. Ash was not collected as part of this sampling activity because it was washed out of the burn area by firefighting water application and rain. Air monitoring also did not occur during these wildfires because the fires were extinguished before air monitoring could be conducted. A description of sample collection is presented below.

A total of two soil samples and two duff samples were collected from the Canoe Gulch (LSF-12) area:

- One 30-point composite soil sample and one duff material sample from the equipment decontamination area.
- One 30-point composite soil sample and one duff material sample from the undisturbed equipment decontamination area.

A total of seven soil samples and four duff samples were collected from the Alexander Ridge (LSF-13) area:

- One 30-point composite soil sample and one duff material sample from the fire site.
- One 30-point composite soil sample from the equipment decontamination area.
- One 30-point composite soil sample and one duff material sample from the undisturbed equipment decontamination area.
- One 30-point composite soil sample and one duff material sample from the personnel decontamination area.
- One 30-point composite soil sample and one duff material sample from the undisturbed personnel decontamination area.
- One 30-point composite soil sample from the disturbed road area 1.
- One 30-point composite soil sample from the disturbed road area 2.

Table 4-1 outlines the samples collected in the 2015 Wildfire Monitoring. **Table 4-2** provides the sample locations by station ID, station description, and analyses conducted for samples collected in the 2015 Wildfire Monitoring. Forest soil and duff material sample locations are presented on **Figure 4-5b.**

Details regarding the collection of samples following these two wildfires are documented in field ROMs OU3-LFM-03 and OU3-LFM-04 for the *Sampling and Analysis Plan/Quality Assurance Project Plan, Operable Unit 3, Libby Asbestos Superfund Site, Wildfire Contingency Monitoring Plan, Revision 3* (EPA, 2015d).

All soils samples were sent to the SPF for preparation and to EMSL for analysis of LAA by PLM-VE and PLM-Grav. Duff material was analyzed for LAA by TEM.

Detailed information on the wildfire monitoring sampling can be found in the *DSR* (CDM Smith, 2016). The results of the wildfire monitoring sampling are summarized in **Section 5.0** of this report.

4.7 AMBIENT / PERIMETER AIR INVESTIGATIONS

Air monitoring under ambient conditions in the OU3 Study Area was completed as part of the Phase I and Phase II Part B sampling programs. The objective of the Phase I and Phase IIB ambient air sampling programs was to assess fiber releases from the Former Mine Area to adjacent downwind areas under current site conditions. Two rounds of monitoring were performed, the first occurred in the fall of 2007 and the second in the summer/fall of 2008. Perimeter air was also collected in 2015 during the slash pile burn and the prescribed understory burn. Perimeter air samples were collected at varying distances from a predetermined location to monitor for potential releases of LAA to downwind locations as a result of the burn study activities. **Table 4-1** outlines the number samples collected for ambient/perimeter air by sampling phase/event. **Table 4-2** provides the ambient/perimeter air sampling locations by station ID,

description, sampling phase/event, and analyses conducted. Ambient/perimeter air sample locations that were analyzed for LAA are presented on **Figures 4-7a** and **4-7b** respectively. Detailed results for LAA detected in ambient/perimeter air samples collected throughout the OU3 Study Area are provided and discussed in **Section 5.0**.

4.7.1 Phase I (2007) – Sampling Activities

The objective of the Phase I ambient air sampling program was to collect data to obtain a preliminary characterization of the nature and extent of potential impacts resulting from historical mining, milling, and activities ancillary to mining and milling (e.g., subsequent handling and transport of mined material). Eight (8) stationary air monitors were placed in two roughly concentric semi-circles around the mine area to evaluate LAA concentrations in ambient air. Station locations were placed north, northeast, east, generally downwind, and generally upwind of the Former Mine Area. The semi-circle was placed close to the boundary of the disturbed mine area (air station locations A-4, A-5, A-6, and A-8), and the semi-circle was close to the perimeter of the property owned by Grace (air station locations A-1, A-2, A-3, and A-7). Four (4) ambient air samples were collected, one every five days for each of the eight stations, for a total of 32 samples collected over a 20-day period per station. Sample were collected at a height of approximately six ft. above ground level using low-flow (2 liters per minute [l/min]) stationary air monitors. The design air volume to be sampled during each five-day period was 14,400 liters, however due to pump faults and flow-rate variance, the actual volumes sampled during each period ranged from 9,987 liters to 14,402 liters. Sample results from the Phase I program were initially intended to be screening level but were later combined with results from other ambient air samples for the Libby Site to support the risk assessment calculations (EPA, 2007b).

Table 4-1 outlines the number of ambient air samples collected in Phase I. **Table 4-2** provides the ambient air sampling locations by station ID, station description, and analyses conducted for ambient air collected in Phase I. Ambient Air sample locations and the OU3 wind rose are presented on **Figure 4-7a**.

Samples were collected in accordance with the *Phase I Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site* (EPA, 2007b). The ambient air filters were sent to EMSL laboratory for analysis of LAA by TEM. Filters were prepared directly and analyzed in accordance with ISO 10312:1995(E) with all applicable Libby Site-specific laboratory modifications.

Detailed information on the Phase I field sampling effort, including all associated field documentation, is provided in the *Phase I FSSR* (MWH, 2007) and the results are summarized in **Section 5.0** of this report.

4.7.2 Phase II, Part B (2008) – Sampling Activities

None of the Phase I ambient air samples contained detectable levels of LAA. Refer to the *DSR* (CDM Smith, 2016). However, the data were not considered to be sufficient because they were collected during a time of frequent rain (so the potential for release may have been reduced) and because the sampling period only spanned a time period of 20 days. Thus, additional ambient air data were collected as part of the Phase II Part B sampling program.

A total of eight (8) stationary ambient air monitors were established around the perimeter of the Former Mine Area. Stations A-4, A-5, A-6 and A-8 were placed at the same locations as were sampled in Phase I, while stations A-9 to A-12 were new stations. As indicated, three stations

were located to the north and one was located to the east of the Former Mine Area, since available meteorological data indicate that the predominant wind direction is to the northeast. Stations A-1, A-2, and A-3 were not utilized as sample locations for Phase II. Three stations were located along the southern perimeter to capture releases that could occur during wind reversals. Sixty-five (65) total samples were collected during eight bi-weekly sampling periods. Each sampling period was five days (120 hours) with a low flow pump rate of 2 l/min; the design air volume to be sampled during each five-day sampling period was 14,400 liters. Due to flow-rate variance the actual volumes sampled during each period ranged from 55,680 liters to 14,663 liters, averaging 13,639 liters.

Table 4-1 outlines the number of ambient air samples collected in Phase II Part B. **Table 4-2** provides the ambient air sampling locations by station ID, station description, and analyses conducted for ambient air collected in Phase II Part B. Ambient Air sample locations and the OU3 windrose are presented on **Figure 4-a7**.

Samples were collected in accordance with the *Phase II Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site Part B: Ambient Air and Groundwater* (EPA, 2008e). The ambient air filters were sent to EMSL laboratory for analysis of LAA by TEM. Filters were prepared directly and analyzed in accordance with ISO 10312:1995(E) with all applicable Libby Site-specific laboratory modifications.

Detailed information on the Phase II Part B field sampling effort, including all associated field documentation, is provided in the *Phase II FSSR* (MWH, 2009) and the results are summarized in **Section 5.0** of this report.

4.7.3 Wood-burning Stove Ash Removal (2012) – Sampling Activities

The objective of the Wood-burning Stove Ash Removal investigation is presented in **Section 4.6.6**. The tasks performed as part of this investigation included the burning of wood in a wood-burning stove and the collection of personal air samples under an ABS sampling scenario of a person emptying the ash from the interior of the stove. Perimeter air monitoring also was conducted during the wood burning and stove emptying events to verify that ABS activities did not result in releases to air outside of the ABS area. Details on the firewood collected for this investigation are presented in **Section 4.6.6** and **Figure 4-5b** and details on the ABS collected for this investigation are presented in **Section 4.8.5**.

Perimeter air samples were collected from a stationary air monitor placed at the perimeter of the investigation area in a downwind direction from the woodstove to monitor any potential releases. Two perimeter air samples were collected for each ABS event. One perimeter air sample had a sample duration that encompassed the entire two days of an individual ABS event (i.e., the duration of the burning, cooling, and ABS activities). The other perimeter air sample was collected only during the six hour burning time period for rapid turnaround analysis to monitor potential releases from the woodstoves during the burning activity. The six hour perimeter air samples were collected at a flow rate of 5 l/min, while the two day perimeter air samples were collected at a flow rate of 2.5 l/min. A total of three two day perimeter air samples and three six hour perimeter air samples were collected and analyzed by TEM.

Table 4-1 outlines the number of perimeter air samples collected in the Wood-burning Stove Ash Removal. **Table 4-2** provides the perimeter air sampling locations by station ID, station description, and analyses conducted for perimeter air collected in the Wood-burning Stove Ash Removal Program.

Samples were collected in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan: Wood-Burning Stove Ash Removal Activity Based Sampling, Libby Asbestos Site, Operable Unit 4, Libby, Montana. Revision 0* (CDM Smith, 2012).

Each perimeter air filter was prepared for analysis by using direct preparation methods. The filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E) with all applicable Libby Site-specific laboratory modifications.

Detailed information on the 2012 Wood-burning Stove Ash Removal sampling effort, including associated field documentation, can be found in the *Data Summary Report: Wood-burning Stove Ash Removal Activity-Based Sampling* (CDM Smith, 2013a). The results of the investigation are summarized in **Section 5.0** of this report.

4.7.4 Souse Gulch Wildfire Monitoring (2013) - Sampling Activities

The objective of the 2013 Souse Gulch Wildfire Monitoring was to collect opportunistic perimeter air samples during a natural wildfire that occurred in the OU3 Study Area. Sample pumps were set to collect at 2 l/min. 24-hour samples were collected from each of three stationary air monitors and 4-hour samples were collected from a mobile monitor placed downwind of the fire for the duration of the wildfire event. The mobile station was used to represent an area downwind of the fire. The actual location selected for the mobile sampler depended upon the ease of access for the truck hauling the sample equipment and safety concerns for sampling personnel (e.g., conditions of the fire). The monitor was placed on a tripod in the back of the truck. During sample collection, the coordinates of the monitor were recorded, as well as the wind direction and speed. This information was used with data on the fire location to establish the distance and direction of the monitor relative to the fire. Samples also were collected from inside air-support craft and near ground-based firefighters responding to the wildfire in the OU3 Study Area (refer to **Section 4.8.7**). Samples were analyzed by TEM under low magnification. Ash samples from the burn area also were collected following the fire (refer to **Section 4.6.8**).

Two perimeter samples were collected, prepared directly, and analyzed for LAA by TEM.

Table 4-1 outlines the number of perimeter air samples collected in the 2013 Souse Gulch Wildfire Monitoring sampling. **Table 4-2** provides the perimeter air sampling locations by station ID, station description, and analyses conducted for perimeter air collected in the 2013 Souse Gulch Wildfire Monitoring. Ambient air sample locations are presented on **Figure 4-7b.**

All sampling was conducted in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan, Operable Unit 3, Libby Asbestos Superfund Site, Wildfire Contingency Monitoring Plan, Revision 33* (EPA, 2015d). The ABS air filters were sent to the EMSL laboratories for analysis of LAA by TEM. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), and, with all applicable Libby Site-specific laboratory modifications, and the results are summarized in **Section 5.0** of this report.

4.7.5 Slash Pile Burn (2015) - Sampling Activities

The study design was to perform a controlled prescribed slash pile burn and to collect samples to measure LAA concentrations in the air that result from the fire. Perimeter air samples were collected before, during, and after the burn to measure LAA concentrations in air at varying

distances in close proximity to the burn area to provide information on the potential for offsite migration of LAA. Refer to **Section 4.6.11** above for details on the goal of this EPA study.

Because wind directions varied during the slash pile burn activities, 12 air monitoring stations were placed around the burn area for perimeter air sampling collection before, during, and after (for two days) the burn. The stations were placed approximately 50,100, and 200 ft. away from the edge of the fire line nearest to the burn area. Four sampling stations for each distance interval were positioned at approximately each compass direction (i.e., north, south, east, and west). Each monitoring location had a high volume pump and a low volume pump.

Perimeter air samples were collected for approximately three hours at only the four perimeter air monitors 50 feet from the edge of the fire line before the burn event (after the creation of the slash pile, fire line, and fuel breaks).

During the slash pile burn, perimeter air samples were collected at the 12 perimeter monitoring stations starting when the fire began generating smoke. During the burn and mop-up activities (refer to **Section 4.8.10**), perimeter air samples were collected for approximately six hours. Air filters were changed out every three hours throughout the burn and the subsequent "mop-up" activities.

After the burn, perimeter air samples were collected for two additional days from only each of the four perimeter air monitors located 50 feet from the edge of the fire line. On each day, two samples (one in the morning and one in the afternoon) were collected from each of the four perimeter air monitors. The duration of each sample was approximately three hours.

A total of 88 perimeter air samples were collected, 44 of which were analyzed for LAA (4 samples before the burn, 24 during the burn, and 16 after the burn). All 44 air filters were prepared directly for analysis by TEM.

Table 4-1 outlines the number of perimeter air samples collected in the Slash Pile Burn Program. **Table 4-2** provides the perimeter air sampling locations by station ID, station description, and analyses conducted for perimeter air collected in Slash Pile Burn Program. Perimeter air sample locations are presented on **Figure 4-7b**.

Samples were collected in accordance with the *Slash Pile Burn Activity Based Sampling Rev. 0 Quality Assurance Project Plan* (USACE, 2015a). The perimeter air filters were sent to EMSL laboratory and Environmental Services Assistance Team Region 8 (ESATR8) laboratory for analysis of LAA by TEM. The high volume filter was analyzed in preference to the low volume filter and if the high volume filter was deemed to be overloaded (i.e., >25% particulate loading on the filter) by the analytical laboratory, then the low volume filter was analyzed. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), with all applicable Libby Site-specific laboratory modifications.

Detailed information on the 2015 slash pile burn investigation sampling effort, including all associated field documentation, is provided in the *2015 FSSR* (MWH, 2016b). The results of the investigation are summarized in **Section 5.0** of this report.

4.7.6 Low-Intensity Prescribed Understory Burn (2015) - Sampling Activities

The objective of the Low-Intensity Prescribed Understory Burn investigation was to perform a small-scale, low-intensity controlled prescribed understory burn and to collect samples to

measure LAA concentrations in the air that resulted from the fire and associated firefighter disturbance activities. Perimeter air samples were collected before, during, and after the burn to measure LAA concentrations in air at varying distances in close proximity to the prescribed understory burn area to provide information on the potential for offsite migration of LAA. Refer to **Section 4.6.12** above for details on the goal of this EPA study.

Because wind directions varied during the understory burn activities, 12 air monitoring stations were placed around the burn area for perimeter air sampling before, during, and after (two days) the burn. The stations were placed approximately 50, 100, and 200 ft. away from the edge of the fire line nearest to the burn area. Four sampling stations for each distance interval were positioned at approximately each compass direction (i.e., north, south, east, and west). Each monitoring location had a high volume pump and a low volume pump.

Perimeter air samples were collected for approximately four hours at only the four perimeter air monitors 50 feet from the edge of the fire line prior to the burn event. The pre-burn sampling was conducted approximately one month prior to conducting the burn. The burn could not take place directly after the pre-burn sampling due to rainy weather conditions. Therefore, the burn sampling was postponed for approximately one month.

During the understory burn, perimeter samples were collected at 12 perimeter monitor stations (four monitor stations at each of three distances) starting after the fire was ignited. The sample duration for each sample was two hours (1-hour during the burn and during the 1-hour mop-up activity [refer to **Section 4.8.11**]). For the 50-foot perimeter monitors, each location had a high volume pump and a low volume pump, and for the 100-foot and 200-foot perimeter monitors, each location only had a high volume pump.

After the burn, perimeter air samples were collected for two days from only each of the four 50-foot perimeter air monitors. On each day, two samples (one in the morning and one in the afternoon) were collected from each of the four perimeter air monitors. The total sample duration was eight hours per day (4 hours in the morning and 4 hours in the afternoon) and air filters were changed after 4 hours.

A total of 60 perimeter air samples were collected, 33 of which were analyzed for LAA (4 samples before the burn, 13 during the burn, and 16 after the burn). Of the 33 samples, 29 were prepared directly and 4 were prepared indirectly for analysis by TEM.

Table 4-1 outlines the number of perimeter air samples collected in the Understory Burn Program. **Table 4-2** provides the perimeter air sampling locations by station ID, station description, and analyses conducted for perimeter air collected in Understory Burn Program. Perimeter air sample locations are presented on **Figure 4-7b**.

Samples were collected in accordance with the *Low-Intensity Prescribed Understory Burn Activity -Based Sampling Rev. 0 Quality Assurance Project Plan* (USACE, 2015b).

The perimeter air filters were sent to EMSL laboratory, ESATR8, and Hygeia Laboratories, Inc. for analysis of LAA by TEM. Perimeter air sample analysis methods for the understory burn were the same as described above in **Section 4.74.** Detailed information on the 2015 understory burn investigation field sampling effort, including all associated field documentation, is provided in the *2015 FSSR* (MWH, 2016b). The results of the investigation are summarized in **Section 5.0** of this report.

4.8 ACTIVITY-BASED SAMPLING AIR SAMPLING INVESTIGATIONS

ABS is a sampling technique that is used to measure air concentrations during disturbances of materials containing LAA. During ABS, air monitors are worn by personnel who are engaged in a variety of material disturbance activities, and the resulting air filters are analyzed to establish the concentration of LAA in air. These air concentrations can then be used to estimate exposures for the purposes of evaluating potential human health risks.

ABS air samples were collected in the OU3 Study Area as part of the Phase III, Phase IV Part A, and Phase V Part A sampling events. Additional sampling events were conducted in and around the OU3 Study Area between 2012 and 2015 to evaluate a variety of LAA material disturbance scenarios. All collected ABS air samples were analyzed for LAA. The following sections summarize the ABS programs. **Table 4-1** outlines the number samples collected for ABS air by sampling phase/event. **Table 4-2** provides the ABS air sampling locations by station ID, description, sampling phase/event, and analyses conducted. ABS air sample locations that were analyzed for LAA are presented on **Figure 4-8.** Detailed results for LAA detected in ABS air samples collected throughout the OU3 Study Area are provided and discussed in **Section 5.0.**

4.8.1 Phase III (2009) – Sampling Activities

The objective of the Phase III ABS was to evaluate human receptors that could potentially be exposed to LAA in the OU3 Study Area, including recreational visitors in the forested area and along the OU3 Study Area streams and ponds, as well as wood harvesters. The Phase III sampling program focused on the collection of ABS data to evaluate LAA exposures to recreational visitors in the forested area during the following types of activities:

- All-terrain vehicle (ATV) riding
- Hiking
- Wood-gathering
- Fire-pit digging
- Campfire burning

Twenty ABS areas were identified as candidate areas for evaluation in Phase III and were dispersed based on the large-scale spatial variability of measured LAA levels in forest soil, duff material, and tree bark, as well as inspection of available maps of roads, trails, and terrain in the OU3 Study Area. Eleven of these areas, predominately in the downwind direction (north-northeast of the mine), were selected for ABS evaluation. For each ABS area, two ABS personnel performed the following scripted activities:

Script 1. This script was designed to simulate recreational ATV riding in the forested area around the Former Mine Area. In this script, two ABS personnel rode individual ATVs. Personnel switched positions (leader/follower) after half of the sampling time had elapsed. Each person was in the leader/follower position for 10 minutes for a total of 20 minutes for this activity.

Script 2. This script was designed to simulate recreational visitor potential exposures while hiking in the forested area around the Former Mine Area. In this script, two ABS personnel hiked and then switched positions (leader/follower) after half of the sampling time had elapsed. Each person was in the leader/follower position for 40 minutes for a total of 80 minutes for this activity.

Script 3. This script was designed to simulate potential exposures during three campfire building scenarios: collecting wood for the campfire, digging a fire pit, and building and standing near a campfire. To limit the potential for an unintentional, uncontrolled forest fire, this activity did not occur in the ABS area, but was conducted on Grace owned property near Rainy Creek Road and Highway 37 (a significantly less vegetated area formerly known as the Flyway) using the wood collected from the ABS area. This activity lasted from 20 minutes to 30 minutes.

Two ABS samples were generated for each person for ATV riding and hiking scenarios and three ABS samples were generated for each person for fire building scenarios. Each person was wearing two air sampling pumps, a 4 l/min high volume pump and a 2 l/min low volume pump. ABS events were conducted at each area approximately every 10 days, starting at the end of August through the beginning of November 2009.

A total of 454 ABS samples were collected, 227 of which were analyzed for LAA. All air filters were prepared directly for analysis by TEM.

Table 4-1 outlines the number of ABS air samples collected in Phase III. **Table 4-2** provides the ABS air sampling locations by station ID, station description, and analyses conducted for ABS air collected in Phase III. ABS air sample locations are presented on **Figure 4-8**.

Samples were collected in accordance with the *Remedial Investigation for Operable Unit 3 Libby Asbestos Superfund Site Phase III Sampling and Analysis Plan* (EPA, 2009c).

The ABS air filters were sent to EMSL laboratory and Hygeia Laboratories, Inc. for analysis of LAA by TEM. The high volume filter was analyzed in preference to the low volume filter and if the high volume filter was deemed to be overloaded (i.e., >25% particulate loading on the filter) by the analytical laboratory, then the low volume filter was analyzed. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), with all applicable Libby Site-specific laboratory modifications.

Detailed information on the Phase III field sampling effort, including all associated field documentation, is provided in the *Phase III Activity-Based Sampling Summary Report* (MWH, 2010) and the results are summarized in **Section 5.0** of this report.

4.8.2 Phase IV, Part A (2010) – Sampling Activities

The objective of the Phase IV Part A sampling program focused on the collection of ABS data to evaluate potential LAA exposures to recreational visitors along the OU3 Study Area streams and ponds, residential wood harvesters, USFS workers, and fire fighters in the forested area (under staged fire-fighting conditions). In addition, the Phase IV Part A SAP included a plan for the collection of opportunistic air samples during natural forest fires in the OU3 Study Area. For the purposes of the Phase IV Part A ABS effort, only a subset of the 11 ABS areas evaluated in the Phase III study were sampled. For most ABS scenarios evaluated in the Phase IV Part A effort, three ABS areas were selected to represent locations “Near” (ABS Area 10), “Intermediate” (ABS Area 7), and “Far” (ABS Area 2) from the Former Mine Area center. Although the study design was to perform ABS activities in area ABS Area 10, the location of the activities was modified at the time of collection to be located about one mile further downwind, closer to the Phase III ABS Area 6. Thus, to avoid potential confusion, the location of this area is referred to as ABS Area 6’. ABS activities were separated into 6 different “scripts” as follows:

Script 1. This script was designed to simulate recreational visitor potential exposures while hiking and antler hunting along LRC between Highway 37 and the Grace property line (refer to the "LRC Study Area" in **Figure 4-8**). The terrain along LRC is overgrown and there are no established trails; however, trespassers could enter this area near Highway 37 although it is more likely that they would use Rainy Creek Road. In this script, two ABS personnel walked up along the banks of the creek, vigorously disturbing bushes and other vegetation as needed to move along the bank of the creek to simulate walking/hiking. Activities also included the samplers using their hands to push aside ground vegetation to simulate hunting for shed antlers. Personnel switched positions (leader/follower) after half of the sampling time has elapsed. Five sampling events were conducted in August 2010.

Script 2. This script was designed to simulate potential exposures during non-commercial (e.g., residential) wood harvesting activities in the forested area in the OU3 Study Area. The script included two types of activity: 2A) driving to and from the wood harvesting area, and 2B) felling, limbing, cutting, and stacking harvested wood. Two ABS personnel performed the scripted activities in each ABS area during each sampling event. ABS was conducted in ABS Area 2, ABS Area 7, and ABS Area 6' (refer to **Figure 4-8**). Five sampling events were conducted in each ABS area between July and August 2010.

Script 3. The first part of this script (3A, 3B, 3C) was designed to simulate potential exposures to USFS workers during activities routinely performed as part of the USFS land management responsibilities. The script included three types of activities: 3A) maintenance of roads and trails, 3B) thinning of trees and vegetation, and 3C) surveying trees (i.e., stand examination). The second part of this script (3D, 3E) was designed to simulate exposures to USFS workers during fire-fighting activities. The script included two types of activities: 3D) cutting fire lines by hand using a Pulaski tool, and 3E) cutting fire lines using heavy equipment (e.g., a bulldozer or tractor plow). Two ABS personnel performed the scripted activities in each ABS area during each sampling event. ABS was conducted in ABS Area 2, ABS Area 7, and ABS Area 6' (refer to **Figure 4-8**). Five sampling events were conducted in each ABS area between July and August 2010.

Script 4. This script was designed to simulate potential exposures to ground-based fire fighters from LAA in air released by burning of contaminated duff material and trees in the OU3 Study Area. Personal and stationary air samples were to be collected during a simulated forest fire, which was to be achieved by the burning two large slash piles in the OU3 Study Area (refer to **Figure 4-8** for slash pile locations). However, due to concerns about the potential for an unintentional, uncontrolled forest fire, this script was not performed.

Script 5. This script was designed to provide data on potential exposures to aircraft pilots during fire suppression flights from LAA in air released by burning of contaminated duff material and trees in the OU3 Study Area. Script 5A was intended to collect data during a simulated forest fire (i.e., the slash pile burn). Script 5B was designed to collect opportunistic samples during natural forest fires in the OU3 Study Area, by placing an air monitor in the cockpit of responding aircraft. As noted above, the slash pile burn was not conducted and no wildfires had occurred in OU3 since the development of this 2010 SAP, until the 2013 Souse Gulch wildfire (refer to **Section 4.8.7**). Thus, no data had been collected, except for the opportunistic samples during the 2013 Souse Gulch wildfire (Note: Script 5B was superseded by the *OU3 Wildfire Contingency Air Monitoring Plan, Revision 3* [EPA, 2015d]).

Script 6. This script was designed to provide data on potential residential exposures from LAA in air during natural forest fires in the OU3 Study Area. As noted above, no wildfires have occurred

in the OU3 Study Area since the development of this SAP. Thus, no data had been collected, except for the opportunistic samples collected during the 2013 Souse Gulch wildfire (Note: This script and the associated SAP Addendum that was created to support a fire fighter ABS effort were superseded by the *OU3 Wildfire Contingency Air Monitoring Plan, Revision 3* [EPA, 2015d]).

During each of the sampling events each person was wearing three air sampling pumps, a 4 l/min high volume pump, a 2 l/min low volume pump, and a 1 l/min low volume pump.

A total of 756 ABS samples were collected, 252 of which were analyzed for LAA. Of the 252 samples, 130 were prepared directly and 122 were prepared indirectly for analysis by TEM.

Table 4-1 outlines the number of ABS air samples collected in Phase IV Part A. **Table 4-2** provides the ABS air sampling locations by station ID, station description, and analyses conducted for ABS air collected in Phase IV Part A. ABS air sample locations are presented on **Figure 4-8**.

Samples for scripts 1 through 5 were collected in accordance with the *Remedial Investigation for Operable Unit 3 Libby Asbestos Superfund Site Phase IV Sampling and Analysis Plan Part A – Data to Support Human Health Risk Assessment* (EPA, 2010b).

The ABS air filters were sent to EMSL laboratory, ESATR8, and Hygeia Laboratories, Inc. for analysis of LAA by TEM. The high volume filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E). If the high volume filter was deemed to be overloaded (i.e., >25% particulate loading on the filter) by the analytical laboratory, then the low volume filter was analyzed in preference to performing an indirect preparation on the high volume filter. If the low volume filter was deemed to be overloaded, an indirect preparation (with ashing) was performed of the high volume filter. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), with all applicable Libby Site-specific laboratory modifications.

Detailed information on the Phase IV Part A field sampling effort, including all associated field documentation, is provided in *Operable Unit 3 Phase IV Remedial Investigation Field Data Summary Report, Activity–Based Sampling* (MWH, 2011) and the results are summarized in **Section 5.0** of this report.

4.8.3 Phase V, Part A (2012) ABS – Sampling Activities

The objective of Phase V Part A was to collect ABS data to evaluate potential exposures to LAA by recreational visitors along the Kootenai River. The ABS air sampling was performed on a sand bar in the Kootenai River immediately downstream of the Rainy Creek. The ABS sampling design is discussed in detail in the *Final Phase V, Part A: Kootenai River Surface Water, Sediment, and Activity-Based Sampling SAP/QAPP* (EPA, 2012c) and is summarized below.

The ABS script was designed to simulate activities that are representative of actions that might be performed by local river guides and recreational visitors on the sand bar. The ABS script included landing a boat on the sand bar, walking around and simulating an individual fishing along the edges of the sand bar, and departing by boat. A team of two samplers landed a boat on the sand bar; the samplers shuffled their feet and gently kicked sediment and rock along the edges of the sand bar for five minutes. Then, the two samplers walked around the sand bar for 50 minutes, staying near the edge and occasionally crossing through the interior of the ABS area, to simulate an individual moving about the sand bar from one fishing location to another. Once 50 minutes had elapsed, the samplers loaded and launched the boat (shuffling their feet and gently

kicking sediment and rock in the process for five minutes). The total ABS time interval was 60 minutes.

ABS air samples were collected on the sandbar on the afternoon of September 19, 2012, during low-flow conditions within the Kootenai River. During the ABS event, two replicate ABS air samples were collected for each actor, one using a 4 l/min high volume pump and one using a 2 l/min low volume pump. Only the two high volume filters were analyzed; the two low volume filters were archived as per specifications in the *Final Phase V, Part A: Kootenai River Surface Water, Sediment, and Activity-Based Sampling SAP/QAPP* (EPA, 2012c).

Four ABS samples were collected, two of which were analyzed for LAA. All air filters were prepared directly for analysis by TEM, refer to **Figure 4-8** sample location ID (ISLAND) where these samples were collected

Table 4-1 outlines the number of ABS air samples collected in Phase V Part A. **Table 4-2** provides the ABS air sampling locations by station ID, station description, and analyses conducted for ABS air collected in Phase V Part A. ABS air sample locations are presented on **Figure 4-8**.

Samples were collected in accordance with the *Sampling and Analysis Plan / Quality Assurance Project Plan for Operable Unit 3, Libby Asbestos Superfund Site Phase V, Part A: Kootenai River Surface Water, Sediment, and Activity-based Sampling* (EPA, 2012c).

The ABS air filters were sent to the EMSL laboratory for analysis of LAA by TEM. The high volume filter was analyzed in preference to the low volume filter and if the high volume filter was deemed to be overloaded (i.e., >25% particulate loading on the filter) by the analytical laboratory, then the low volume filter was analyzed. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), with all applicable Libby Site-specific laboratory modifications. Detailed information on the Phase V, Part A field sampling effort, including all associated field documentation, is provided in the *Phase V Remedial Investigation Field Summary Report* (MWH, 2013c) and the results are summarized in **Section 5.0** of this report.

4.8.4 Commercial Logging (2012) – Sampling Activities

The objective of the 2012 Commercial Logging investigation was to collect air samples during commercial logging activities to provide measured data on potential exposures to LAA for workers involved in commercial logging activities in the forest near the Former Mine Area. ABS air sampling was conducted during commercial logging activities in an area near the Former Mine Area to evaluate potential LAA exposures. Study design and methods are summarized below:

Study Location. Available data on levels of LAA measured in tree bark, soil, and duff material indicate that, in general, the levels of LAA tend to decrease with distance away from the center of the Former Mine Area (discussed in more detail in **Section 5.0**). The commercial logging study was performed in an area close to the Former Mine Area (in the downwind direction), where elevated concentrations of LAA have been reported in tree bark and duff material in previous studies. This study area was chosen to be representative of the high end of the potential exposures that may occur and is located on Grace property (a restricted area).

Timing and Duration of the ABS Effort. Commercial logging ABS efforts were conducted in September of 2012, when environmental conditions were likely to be driest and potential airborne LAA releases were highest. There were no sampling time durations established for this study. Rather, commercial logging workers (contracted by Grace) were to perform ABS during the

logging of approximately 100 trees. ABS samples collected in this study were typically one to two hours in duration and for activities spanning more than two hours, air filters were changed out every two hours to limit potential filter overloading.

Characterization of Soil, Duff material, and Tree Bark from the Forested Area. Samples of tree bark and duff material within the study area were collected and analyzed for LAA; these sampling designs are described in **Section 4.6.3**.

Characterization of LAA Levels in Air During Commercial Logging Activities. ABS samples were collected for a range of activities representative of commercial logging activities including: hand felling, hooking and skidding, mechanical processing, sample location restoration, and milling processes. These activities are described below.

- **Hand-Felling.** The felling of timber is the process of severing the tree from the stump and placing it on the ground. Hand-felling is the traditional method of skilled personnel, herein referred to as a sawyer, utilizing a handheld chain saw to cut the timber. ABS samples for the felling scenario were collected using personal air sampling pumps with the filter located on the shoulder of the sawyer.
- **Hooking and Skidding.** The hooking and skidding of timber is the process of dragging felled trees to a centralized location (the landing area) for further processing or transportation. For this study, trees were moved using a cable skidder, which requires an operator to get off the machine to manually attach trees with cables (or chokers). The activity of attaching chokers to logs is commonly referred to as "hooking." ABS samples for this scenario were collected using personal air sampling pumps with the filter located on the shoulder of the hookers/skidders. The samples represent air levels that occurred during both operations.
- **Mechanical Processing.** Timber processing is the act of cutting limbs from the tree and cutting the tree into the desired length and width. Although mechanical processors vary, most utilize an excavator-type machine that mechanically strips limbs from the tree and cuts the tree into desired lengths. Mechanical processors most often have enclosed cabs in which the operator is stationed through the duration of processing activities. ABS samples for this scenario were collected using personal air sampling pumps with the filter located on the shoulder of the operator inside the cab of the mechanical processing machine.
- **Milling Process.** The milling process is the act of removing bark from cut timber and cutting logs to appropriate size and shape for sale. This activity is commonly performed at a mill site that is remote from the forest. However, for this investigation, logs were cut into slabs and run through a chipper at the onsite landing area to simulate exposures that might occur in an offsite milling operation. ABS samples for this scenario were collected using stationary air monitors located 10 or 30 ft. from the chipper.
- **Sample Location Restoration.** Following harvesting operations, sample location restoration was performed utilizing a bulldozer to remove brush and tree litter from the landing area until the landing area had been cleared and the road restored to its original condition. ABS samples were collected using personal air samplers to represent exposures of the bulldozer operator and also a helper standing on the ground during bulldozing operations.

During each of the sampling events each person was wearing two air sampling pumps, a 4 l/min high volume pump and a 2 l/min low volume pump.

A total of 26 ABS samples were collected, 13 of which were analyzed for LAA. Of these 13 samples, five were prepared directly and eight were prepared indirectly for analysis by TEM. **Table 4-1** outlines the number of ABS air samples collected in the 2012 Commercial Logging. **Table 4-2** provides the ABS air sampling locations by station ID, station description, and analyses conducted for ABS air collected in the 2012 Commercial Logging. ABS air sample locations are presented on **Figure 4-8**.

Samples were collected in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan Operable Unit 3, Libby Asbestos Superfund Site 2012 Commercial Logging Activity-Based Sampling* (EPA, 2012g).

The ABS air filters were sent to the EMSL laboratory for analysis of LAA by TEM. The high volume filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E). If the high volume filter was deemed to be overloaded (i.e., >25% particulate loading on the filter) by the analytical laboratory, then the low volume filter was analyzed in preference to performing an indirect preparation on the high volume filter. If the low volume filter was deemed overloaded, an indirect preparation (with ashing) was performed of the high volume filter. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), with all applicable Libby Site-specific laboratory modifications.

Detailed information on the 2012 commercial logging field sampling effort, including all associated field documentation, is provided in the *2012 Phase V Remedial Investigation FSSR* (MWH, 2013c) and the results are summarized in **Section 5.0** of this report.

4.8.5 Wood-burning Stove Ash Removal (2012) – Sampling Activities

The objective of the Wood-burning Stove Ash Removal investigation is presented in **Section 4.6.6**. The tasks performed as part of this investigation included the burning of wood in a wood-burning stove and the collection of personal air samples under an ABS sampling scenario of a person emptying the ash from the stove.

All ABS activities were conducted inside a temporary enclosure in the vicinity of the Lincoln County landfill, refer to **Figure 4-5b** for landfill location. The temporary enclosure was constructed of posts with polyvinyl sheeting to serve as walls. A wood-burning stove was placed inside the enclosure. Three new EPA-certified wood-burning stoves were utilized (one stove was dedicated to each tree collection location). During wood burning, the walls of the enclosure were removed so that the heat generated by the stove could dissipate into the open air. The enclosure walls were put in place for the ABS stove-emptying activities to simulate an indoor condition. Within this ABS area, the stove-emptying ABS scenario was repeated three times for the varying wood samples collected near the Former Mine Area, near Flower Creek, and near Bear Creek (refer to **Section 4.6.6**). (As noted previously, the Flower Creek and Bear Creek locations are not within the OU3 Study Area, but are included in the RI for the purposes of comparison to the location near the Former Mine Area).

The stove-emptying ABS activities were conducted in basic accordance with the script provided in the *Sampling and Analysis Plan/Quality Assurance Project Plan: Wood-Burning Stove Ash Removal Activity Based Sampling, Libby Asbestos Site, Operable Unit 4, Libby, Montana. Revision 0* (CDM Smith, 2012). In brief the ash was emptied from the woodstove using a long-

handled metal shovel, placing the ash material into a metal ash bucket. Once all of the ash had been shoveled out, a soft-bristled brush was used to sweep up and gather any additional ash material for removal and placed into the ash bucket. There was no specified sampling duration requirement for this ABS scenario. Rather, the scenario continued until the ash had been removed regardless of how long the activity took.

During each of the sampling events, each person wore two air sampling pumps, a 5.5 l/min high volume pump and a 2 l/min low volume pump.

Table 4-1 outlines the number of perimeter air ABS collected in the Wood-burning Stove Ash Removal. **Table 4-2** provides the ABS locations by station ID, station description, and analyses conducted for perimeter air collected in the Wood-burning Stove Ash Removal Program.

Samples were collected in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan: Wood-Burning Stove Ash Removal Activity Based Sampling, Libby Asbestos Site, Operable Unit 4, Libby, Montana. Revision 0* (CDM Smith, 2012).

Eighteen ABS air samples were collected and sent for analysis of LAA by TEM. The high volume filter was analyzed in preference to the low volume filter and all high volume filters were prepared using indirect methods due to high particulate loading levels on both the high volume and low volume filters (CDM Smith, 2013a). Each ABS air filter was prepared for analysis by using indirect preparation methods. The filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E) with all applicable Libby Site-specific laboratory modifications.

Detailed information on the 2012 Wood-burning Stove Ash Removal sampling effort, including associated field documentation, can be found in the *Data Summary Report: Wood-burning Stove Ash Removal Activity-Based Sampling* (CDM Smith, 2013a). The results of the investigation are summarized in **Section 5.0** of this report.

4.8.6 Souse Gulch (2013) – Sampling Activities

At the request of the USACE and the USPHS, FOH conducted environmental duff material/bark sampling and analysis and activity based air sampling on May 5-7, 2013, at the USACE Libby Dam. The USACE has plans to renovate areas of the Souse Gulch Campgrounds near the Libby Dam. Renovations will include excavation of soils and disturbance of forest vegetation (including timber, duff material, and brush). Several trees will have to be cut down. The USACE is concerned that workers may be exposed to elevated levels of LAA when conducting these activates. To establish potential exposure from cutting down trees and disturbing soils, the USACE tasked FOH with collecting representative core bark and duff material samples from trees and soils within the areas of the proposed renovations. In addition, the USACE is responsible for keeping roadways and driving trails in and around the Souse Gulch Campgrounds and Libby Dam areas clean. After each winter, sand used to coat the roadways for safer driving after ice and snow storms and other debris that collects on the roadways-including pine needles are removed using three types of street sweepers. FOH was tasked to collect tree bark, duff material samples, and personal air samples on workers driving the street sweepers and workers driving water trucks used to wet/dampen sand and debris prior to being picked up/swept by the street sweepers. The tree bark and duff material samples are discussed in **Section 4.6.7**.

Activity based air sampling during street sweeping was conducted. Airborne LAA levels were measured during the operation of three different types of street sweepers. The first two, a small

bobcat equipped with an automatic sweeper Model 763H L55 and a Tennant Model 192 Street Sweeper, have no debris pickup capacity or means to pre-wet debris to suppress dust prior to sweeping. A water truck with a water spray system was used to pre-wet the roadway. These two street sweepers followed the water truck. The third sweeper, a Tymco Regenerate Air Systems 600 Air Sweeper has a holding tank for water and a built-in water spray system that pre-wets debris prior to sweeping/picking up. Low volume and high volume air sampling pumps were set up in the sweeper cabs and tubing attached to collect personal air samples for each of the drivers to establish their LAA exposure. Street sweeper drivers suited up into full body disposable clothing and donned HEPA filter respirators. Low volume samples were collected at a flow rate of 2 l/min and were operated for approximately four hours. High volume samples were collected at a flow rate of 4 l/min and were also operated for approximately four hours. A total of 240 liters of air was collected for the low volume samples and 480 liters of air for the high volume samples. The low or high volume samples were analyzed based on particulate loading. Because of particulate loading the low volume samples were analyzed for the USACE personnel operating the bobcat 763H L55 and Tennant Model 192 sweepers. The high volume sample for the USACE worker operating the Tymco Regenerate Air Systems 600 Air Sweeper was analyzed. Samples were analyzed by Reservoirs Environmental Inc. located in Denver, Colorado. Reservoirs Environmental is accredited by the NVLAP for LAA analysis by TEM/PLM.

Eight ABS samples were collected, 5 of which were analyzed for LAA. All air filters were prepared directly for analysis by TEM.

Table 4-1 outlines the number of ABS air samples collected in the 2013 Souse Gulch sampling. **Table 4-2** provides the ABS air sampling locations by station ID, station description, and analyses conducted for ABS air collected in the 2013 Souse Gulch sampling. ABS air sample locations are presented on **Figure 4-8**.

Samples were collected and analyzed in accordance with the SOP provided by the USACE – *Asbestos Activity Based Sampling Street Sweeping Sampling and Analysis Plan Libby Dam Libby, Montana* dated April 2013.The ABS air filters were sent to EMSL laboratories for analysis of LAA by TEM. The high volume filter was analyzed in preference to the low volume filter and if the high volume filter was deemed to be overloaded (i.e., >25% particulate loading on the filter) by the analytical laboratory, then the low volume filter was analyzed. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), with all applicable Libby Site-specific laboratory modifications.

Detailed information on the 2013 Souse Gulch sampling effort, including sampling methodology and associated field documentation, is provided in the *Environmental Duff material/Bark Sampling & Analysis with Activity Based Air Sampling Investigation* (USACE, 2013) and the results are summarized in **Section 5.0** of this report.

4.8.7 Souse Gulch Wildfire Monitoring (2013) -Sampling Activities

The objective of the 2013 Souse Gulch Wildfire Monitoring was to collect opportunistic ABS air samples during a natural wildfire that occurred in the OU3 Study Area. Samples were collected from the cockpit of the responding helicopter and from near ground-based firefighters responding to the natural wildfire in the OU3 Study Area. Samples were analyzed by TEM under low magnification. Additionally, samples of perimeter air were collected during the wildfire and samples of ash from the burn area were collected following the fire (refer to **Sections 4.7.4** and **4.6.8** respectively).

Sixteen ABS samples were collected, prepared directly, and analyzed for LAA by TEM.

Table 4-1 outlines the number of ABS air samples collected in the 2013 Souse Gulch Wildfire Monitoring sampling. **Table 4-2** provides the ABS air sampling locations by station ID, station description, and analyses conducted for ABS air collected in the 2013 Souse Gulch Wildfire Monitoring. ABS air sample locations are presented on **Figure 4-8**.

All sampling was conducted in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan, Operable Unit 3, Libby Asbestos Superfund Site, Wildfire Contingency Monitoring Plan, Revision 33* (EPA, 2015d). The ABS air filters were sent to the EMSL laboratories for analysis of LAA by TEM. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), with all applicable Libby Site-specific laboratory modifications and the results are summarized in **Section 5.0** of this report.

4.8.8 Commercial Logging (2014) – Sampling Activities

The objective of the 2014 Commercial Logging investigation was to collect air samples during commercial logging activities in areas of known low LAA concentrations in tree bark and duff material in the OU3 Study Area to evaluate the exposures of commercial logging workers that harvest trees in areas of known low LAA concentrations. The purpose of this investigation was different than the 2012 commercial logging effort, which was to collect air samples during commercial logging activities to provide measured data on potential exposures to LAA for workers involved in commercial logging activities in the forest near the Former Mine Area (refer to **Section 4.8.4**). As part of this investigation, samples of tree bark and duff material within the study area were collected and analyzed for LAA. Sampling efforts were conducted in August and September of 2014. Study design and methods are summarized below:

Study Location. Available data on levels of LAA measured in tree bark, soil, and duff material indicate that, in general, the levels of LAA tend to decrease with distance away from the center of the mine (as presented in **Section 5.0**). The commercial logging study was performed in an area approximately 4 miles from the center of the Former Mine Area, where low concentrations of LAA have been reported in tree bark and duff material from previous RI phase studies. The study area was chosen to be representative of the low end of the potential exposures that may occur and is located on USFS property (a publicly accessible area).

Timing and Duration of the ABS Effort. Commercial logging ABS efforts were conducted in August and September of 2014, when environmental conditions were dry and potential airborne LAA releases were highest. There were no sampling durations established for this study based on the earlier studies. Rather, commercial logging workers were to perform ABS during the logging of approximately 100 trees. For activities spanning more than two hours, air filters were changed out every two hours to limit potential filter overloading. Although the ABS samples collected in this study were typically one to two hours in duration, the concentrations measured were assumed to be representative of exposures that could occur over the full course of a work day.

Characterization of Duff Material and Tree Bark from the Forested Area. Samples of tree bark and duff material within the study area were collected and analyzed for LAA and these sampling designs are described in **Section 4.6.9**.

Characterization of LAA Levels in Air During Commercial Logging Activities. ABS samples were collected for a range of activities representative of commercial logging activities including:

hand felling, skidding of timber, mechanical processing, milling processes, and sample location restoration these activities are described in **Section 4.8.4**.

During each of the sampling events each person was wearing two air sampling pumps, a 4 l/min high volume pump and a 2 l/min low volume pump.

A total of 58 ABS samples were collected, 29 of which were analyzed for LAA. Of the 29 samples, 27 were prepared directly and two were prepared indirectly for analysis by TEM. **Table 4-1** outlines the number of ABS air samples collected in the 2014 Commercial Logging. **Table 4-2** provides the ABS air sampling locations by station ID, station description, and analyses conducted for ABS air collected in the 2014 Commercial Logging sampling. ABS air sample locations are presented on **Figure 4-8**.

Samples were collected in accordance with the *Quality Assurance Project Plan: Commercial Logging Activity-Based Sampling Libby Asbestos Superfund Site Revision 0* (USACE, 2014a).

The ABS air filters were sent to EMSL laboratories for analysis of LAA by TEM. The high volume filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E). If the high volume filter was deemed to be overloaded (i.e., >25% particulate loading on the filter) by the analytical laboratory, then the low volume filter was analyzed in preference to performing an indirect preparation on the high volume filter. If the low volume filter was deemed to be overloaded, an indirect preparation (with ashing) was performed of the high volume filter. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), with all applicable Libby Site-specific laboratory modifications.

Detailed information on the 2014 Commercial Logging field sampling effort, including all associated field documentation, can be found in the *2014 Commercial Logging Activity-based Sampling* (EPA, 2015e). The results of the investigation are summarized in **Section 5.0** of this report.

4.8.9 Nature and Extent Forest ABS (2014) – Sampling Activities

The objective of the 2014 Nature and Extent investigation was to measure LAA concentrations in outdoor air during ABS at locations along the NPL boundary to estimate potential exposures and risks to firefighting populations that could be exposed to LAA in these forested areas. These risk estimates will be used to inform future decisions on the boundaries of the nature and extent of LAA impact in the forest. This study collected data from 10 sampling locations along the current NPL boundary, collocated with sampling locations evaluated in the Nature and Extent in the Forest investigation (USACE, 2014b). Sampling locations were selected to be spatially representative of the circumference of the NPL boundary, but not duplicative with locations sampled as part of the OU3 Study Area ABS studies. Sampling locations were placed in areas that were accessible via USFS roads and that appeared to have adequate tree cover (based on a cursory review of aerial images). This sampling event was conducted in August of 2014.

Each sampling event began by conducting the fire line ABS. During the event, two individuals participated in the ABS scenario and simulated firefighting activities of constructing a firebreak by hand. A Pulaski tool or other similar device was used to scrape away all combustible material down to mineral soil to establish a line approximately 18 inches wide. The two ABS participants worked side-by-side approximately 10 ft. apart. The ABS activity was performed for a period of 30 minutes. After 15 minutes, the relative positions of the two participants were reversed.

Each sampler wore two different sampling pumps, a 5.5 l/min high volume filter and a 2.0 l/min low volume filter. However, only one of the two air filters for each individual, either the high volume filter or the low volume filter, was analyzed by TEM. Thus, each sampling event included the collection of four fire line ABS air filters, two high volume filters and two low volume filters, of which two filters (one per actor) were analyzed.

In order to maximize the amount of time between the sampling events, the second ABS event was not conducted until the first event was completed for all ten locations. Likewise, the third ABS event was not conducted until the second event was completed for all ten locations.

A total of 120 ABS samples were collected, 60 of which were analyzed for LAA. All air filters were prepared directly for analysis by TEM.

Table 4-1 outlines the number of ABS air samples collected in the 2014 Nature and Extent Forest. **Table 4-2** provides the ABS air sampling locations by station ID, station description, and analyses conducted for ABS air collected in the 2014 Nature and Extent Forest sampling. ABS air sample locations are presented on **Figure 4-9**.

Samples were collected in accordance with the *Quality Assurance Project Plan: Nature and Extent – Forest Activity-Based Sampling Libby Asbestos Superfund Site Revision 1* (USACE, 2014b)

Following ABS air sample collection, one soil sample was collected from each of the ten sampling locations as discussed in **Section 4.6.10**. The ABS air filters were sent to EMSL laboratories and ESATR8 for analysis of LAA by TEM. The high volume filter was analyzed in preference to the low volume filter and if the high volume filter was deemed to be overloaded (i.e., >25% particulate loading on the filter) by the analytical laboratory, then the low volume filter was analyzed. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), with all applicable Libby Site-specific laboratory modifications.

Detailed information on the 2014 Nature and Extent field sampling effort, including all associated field documentation, can be found in the *Nature and Extent Forest Activity-based Sampling* (EPA, 2015f). The results of the investigation are summarized in **Section 5.0** of this report.

4.8.10 Slash Pile Burn (2015) – Sampling Activities

The objective of the Slash Pile Burn investigation was to perform a controlled prescribed slash pile burn and to collect samples to measure LAA concentrations in the air that resulted from the fire. Personal air samples were collected to measure LAA air concentrations in the breathing zone of forest workers while creating the slash pile area (pre-burn sampling). During the burn, personal air samples were collected to measure LAA air concentrations in the breathing zone of individuals near the fire while the slash pile was burning. After the burn, personal air samples were collected to measure LAA air concentrations in the breathing zone of forest workers during "mop-up" activities. Refer to **Section 4.6.11** above for details on the goal of this EPA study.

The pre-burn ABS samples were intended to help characterize LAA exposures related to disturbances of source materials (i.e., tree bark, duff, and soil) during the construction of a slash pile and the associated fire breaks and fire lines. Personal air samples were collected for the excavator operator that constructed the slash pile, fuel break, and fire line. The total sampling duration for this activity was two hours and air sample filters were changed every hour.

Sample collected during the burn were intended to characterize LAA exposures related to smoke releases during a slash pile burn. Two ABS personnel moved around the edges of the slash pile burn area, including locations in the cross-wind and downwind directions, performing the activities to manage and maintain the fire within the burn area. The burn lasted 5 hours and air sample filters were changed out every hour throughout the duration of the ABS activity.

The post-burn mop-up ABS sampling was intended to help characterize LAA exposures related to disturbances of ash and soil in the burn area to characterize exposures during mop-up activities. Once the fire was reduced to a smoldering phase and the entire burn area was deemed safe for personnel and equipment to enter, two ABS personnel performed mop-up activities. Personal air samples were collected for the excavator operator and the hose operator that entered the burn area to cover any remaining hot spots in the burn area with soil. This ABS activity was performed for a total of one hour and included both a “dry” mop-up scenario (i.e., where no water is applied during the mop-up activity) and a “wet” mop-up scenario (i.e., where water is applied during the mop-up activity). During the first 30 minutes, dry mop-up activities were performed using the excavator (i.e., mixing, stirring, and digging up the soil using the bucket of the excavator). During the last 30 minutes, mop-up activities were conducted with the hose operator applying water while the excavator continued using the excavator to extinguish any remaining hot spots. During mop-up activities, air sample filters were changed out every 15 minutes.

For the personal ABS air samples, two filters were collected, a 4 l/min high volume filter and a 2 l/min low volume filter. Either the high volume or low volume filter was then selected in preference and analyzed based upon specifications in the *Slash Pile Burn Activity Based Sampling Rev. 0 Quality Assurance Project Plan* (USACE, 2015a). Sampling locations are presented on **Figure 4-8**.

A total of 36 ABS samples were collected, 18 of which were analyzed for LAA. All air filters were prepared directly for analysis by TEM.

Table 4-1 outlines the number of ABS air samples collected in the Slash Pile Burn event. **Table 4-2** provides the ABS air sampling locations by station ID, station description, and analyses conducted for ABS air collected in the Slash Pile Burn sampling. ABS air sample locations are presented on **Figure 4-8**.

Samples were collected in accordance with the *Slash Pile Burn Activity Based Sampling Rev. 0 Quality Assurance Project Plan* (USACE, 20015a).

The ABS air filters were sent to EMSL laboratories and ESATR8 for analysis of LAA by TEM. The high volume filter was analyzed in preference to the low volume filter and if the high volume filter was deemed to be overloaded (i.e., >25% particulate loading on the filter) by the analytical laboratory, then the low volume filter was analyzed. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), with all applicable Libby Site-specific laboratory modifications.

Detailed information on the 2015 slash pile burn investigation field sampling effort, including all associated field documentation, is provided in the *2015 FSSR* (MWH, 2016b). The results of the investigation are summarized in **Section 5.0** of this report.

4.8.11 Low-Intensity Prescribed Understory Burn (2015) – Sampling Activities

The objective of the Low-Intensity Prescribed Understory Burn investigation was to perform a small-scale, low-intensity controlled prescribed understory burn and to collect samples to measure LAA concentrations in the air that result from the fire and associated firefighter disturbance activities. During the burn and mop-up activity, personal air samples were collected for individuals performing simulated ground-based firefighter activities to measure LAA air concentrations in the breathing zone during these activities. Refer to **Section 4.6.12** above for details on the goal of this EPA study.

Personal air monitoring was performed for two different ABS activities: during the understory burn and during mop-up activities. For both ABS activities air sample filters were changed out every 15 minutes throughout the duration of the ABS activity. During the burn, two ABS personnel moved around the edges of the fire line, monitoring for spot fires, and ensuring the fire perimeter was not compromised using fire suppression hand tools (i.e., Pulaski axe, fire rake, Mcleod tool). The understory burn lasted for approximately one hour. Once the fire was reduced to a smoldering phase and it was been deemed safe for personnel to enter the burn area, two personnel entered the burn area and simulated mop-up fire suppression activities using hand tools. The mop-up ABS activity was performed for a total of one hour and included both a dry mop-up scenario and a wet mop-up scenario, with each scenario conducted for 30 minutes.

Procedures for sample collection, preparation, and analysis are the same as those used for the slash pile burn event described above in **Section 4.8.10**, with the exception of indirect preparation for some of the samples collected. The ABS air filters were sent to EMSL laboratories, Hygeia Laboratories, Inc., and ESATR8 for analysis of LAA by TEM. The high volume filter was used to prepare a minimum of three grids using the grid preparation techniques described in Section 9.3 of ISO 10312:1995(E). If the high volume filter was deemed to be overloaded (i.e., >25% particulate loading on the filter) by the analytical laboratory, then the low volume filter was analyzed in preference to performing an indirect preparation on the high volume filter. If the low volume filter was deemed to be overloaded, an indirect preparation (with ashing) was performed of the high volume filter. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), with all applicable Libby Site-specific laboratory modifications.

A total of 32 ABS samples were collected, 16 of which were analyzed for LAA. Of the 16 samples, eight were prepared directly and eight filters were prepared indirectly for analysis by TEM.

Table 4-1 outlines the number of ABS air samples collected in the Understory Burn event. **Table 4-2** provides the ABS air sampling locations by station ID, station description, and analyses conducted for ABS air collected in the Understory Burn sampling. ABS air sample locations are presented on **Figure 4-8**.

Samples were collected in accordance with the *Low-Intensity Prescribed Understory Burn Activity-Based Sampling Rev. 0 Quality Assurance Project Plan* (USACE, 2015b).

Detailed information on the 2015 understory burn investigation field sampling effort, including all associated field documentation, is provided in the *2015 FSSR* (MWH, 2016b). The results of the investigation are summarized in **Section 5.0** of this report.

4.8.12 Trespasser Activity Based Sampling (2015) – Sampling Activities

The objective of the trespasser activity-based sampling investigation was to determine concentrations of LAA in activity-based air samples during source material disturbance activities in the Former Mine Area. Two trespassing ABS activities were evaluated:

- during ATV riding, on existing roads and trails (on-road) and in the disturbed area of the Former Mine Area off-road, and
- while rock hounding in the mined area.

Each ABS activity was conducted by two field personnel wearing two air monitors, a 4 liter/minute high volume pump and a 2 liter/minute low volume pump, to allow for the collection of two replicate filters (i.e., each filter represents the same sample collection duration, but different total sample air volumes). Only one of the two resulting air filters was selected for analysis, the other filter replicate was archived. To minimize the potential for filter overloading during ABS, air cassettes were changed every 15 minutes throughout each scenario.

There were two ATV riders during each ABS event, a leader and a follower. The distance between the leader and follower depended upon the terrain and amount of dust generated by the leader. The ATV riders traveled at an approximate speed of 10 miles per hour or less, depending on terrain and safety considerations. Riders followed each other throughout the duration of the ABS activity, and the leader and follower riders switched positions every 7-8 minutes throughout the event. As such, each air filter was representative of a leader/follower composite exposure. Two types of ATV riding were performed: 1) on existing roads and trails (on-road), and 2) on the disturbed area of the mine (off-road). There was no set sampling duration for the on-road ATV riding scenario; instead the scenario lasted as long as it took to travel to the end of the route and return back to the beginning of the route The total sampling duration for Route A was 45 minutes, for Route B was 75 minutes, and for Route C was 60 minutes. Three on-road ATV riding ABS events were performed, with each event conducted on one of three pre-determined routes. Three off-road ATV riding ABS events also were performed with each totaling 45 minutes for the sampling duration. The riders attempted to cover as much of the off-road ABS area designated in the SAP as possible during the sampling event.

During the rock hound ABS scenario, two individuals performed rock hound activities simultaneously. Each personnel carried a rock hammer and mimicked people looking for interesting rock and mineral specimens by examining outcrops, rock faces, and waste rock piles, collecting rock specimens in a bucket, and generally walking around the Former Mine Area. After conducting activities at a particular location, the personnel drove to the next location in the ATV, leaving the sampling pumps running while driving between locations. All of the rock hound ABS was performed on the disturbed area of the mine. Each rock hound sampling event sampling duration was a total of 45 minutes, with ABS personnel attempting to cover as much of the ABS area as possible during each sampling event. Three rock hound ABS events were performed.

A total of 120 ABS samples were collected, 60 of which were analyzed for LAA. All 60 air filters were prepared directly for analysis by TEM.

Table 4-1 outlines the number of ABS air samples collected in the Trespasser Activity event. **Table 4-2** provides the ABS air sampling locations by station ID, station description, and analyses conducted for ABS air collected in the Trespasser Activity sampling. ABS air sample locations are presented on **Figure 4-8**.

Samples were collected in accordance with the *Sampling and Analysis Plan / Quality Assurance Project Plan: Operable Unit 3 Study Area, Libby Asbestos Superfund Site Trespasser Activity-Based Sampling* (EPA, 2015c).

The ABS air filters were sent to EMSL laboratories and ESATR8 for analysis of LAA by TEM. The high volume filter was analyzed in preference to the low volume filter and if the high volume filter was deemed to be overloaded (i.e., >25% particulate loading on the filter) by the analytical laboratory, then the low volume filter was analyzed. Filters were prepared and analyzed in accordance with ISO 10312:1995(E), with all applicable Libby Site-specific laboratory modifications.

Detailed information on the 2015 trespasser activity based sampling effort, including all associated field documentation, is provided in the *2015 FSSR* (MWH, 2016b). The results of the investigation are summarized in **Section 5.0** of this report.

4.9 GEOTECHNICAL AND HYDROGEOLOGICAL INVESTIGATIONS

Geotechnical samples were collected as part of two separate events to establish: (1) the geotechnical and engineering characteristics and LAA content of the soils along possible creek diversion channels and in possible borrow source areas; and (2) collect needed geotechnical, geological, and hydrogeological data that will be used in the future as input parameters for various stability, seepage, and geologic analytical models of the KDID. The following sections summarize these field sampling efforts. **Table 4-1** outlines the number samples collected for geotechnical testing by sampling phase/event. **Table 4-2** provides the geotechnical sampling locations by station ID, description, sampling phase/event, and analyses conducted. Geotechnical sample locations are presented on **Figure 4-4a.**

4.9.1 Geotechnical Test Pit Evaluation (2014) - Investigation Activities

This investigation was conducted in June 2014. The objective of the test pit sampling effort was to collect additional field data to establish the geotechnical and engineering characteristics and LAA content of the soils along possible creek diversion channels and in possible borrow source areas (LAA soil samples collected as part of this investigation are discussed above in **Section 4.5.4**).

The following tasks were conducted during this effort:

1. Performed a reconnaissance (refer to S**ection 4.5.5)** along Rainy, Fleetwood, and Carney Creeks and intermittent tributaries. The reconnaissance also included the stretch of the LRC down to monitoring location LRC-06.
2. Excavated 27 test pits and evaluated geotechnical and engineering characteristics of soils and depth to groundwater along the potential creek diversion channels and along the LRC.
3. Evaluated the 27 excavated test pits for extent, thickness, and geotechnical and engineering characteristics of sources of potential borrow materials downstream of the KDID and in the potential aggregate borrow pit along the LRC for future use during remedial action construction activities.
4. Sampled near surface soils for both geotechnical properties and LAA analysis.

The excavation of 27 test pits was completed at locations surrounding and within the KDID and tailings impoundment materials, along potential creek diversions and, within potential construction borrow source areas. Test pits were excavated using an excavator to depths of up to 15 ft. bgs. All test pits were logged by a field geologist to identify and characterize soil type according to the USCS and describe the materials encountered according to interpretations of the type and nature of the deposit. Detailed field logging of the subsurface materials, stratigraphy and encountered obstructions (e.g., tree roots, buried pipes, etc.), as well as observations concerning groundwater infiltration were recorded on field logs during the excavation process. Composite soil samples of varying volumes were collected for geotechnical analysis (samples designated GT-XX). Volumes were based upon geotechnical testing requirements.

Along with the text pit samples, bulk samples were collected from the near surface of the Coarse Tailings Pile (samples designated CT-XX) located just east of the KDID, and from the Waste Rock Piles (samples designated WR-XX) located within the Carney Creek valley to the southeast of the KDID. The purpose of these samples was to better characterize the geotechnical composition of the various piles near the surface. Representative samples were collected by digging a hole with a hand shovel and collecting samples from one to three ft. below ground surface. Collected samples are representative of the fraction of the material smaller than three inches in diameter.

Geotechnical index testing was performed on 41 unique samples collected from the test pits. The following testing methods and quantities were performed as part of this program (ASTM, 2014):

- Natural Moisture Content Tests (ASTM D2216); *26 samples*
- Particle Size Analysis – Gradation Tests (ASTM D6913); *31 samples*
- Particle Size Analysis – Gradation with Hydrometer Tests (ASTM D422); *9 samples*
- Atterberg Limit Tests (ASTM D4318); *30 samples*
- Standard Proctor Compaction (ASTM D698); *3 samples*

Additionally, geotechnical index testing was performed on 15 unique near surface samples. The following testing methods and quantities were performed as part of this program (ASTM, 2014):

- Particle Size Analysis - Gradation Tests (ASTM D6913); *9 samples*
- Particle Size Analysis – Gradation with Hydrometer Tests (ASTM D422); *6 samples*
- Atterberg Limit Tests (ASTM D4318); *4 samples*

Based on the results, samples were classified according to ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (USCS).

Table 4-1, Panel B shows the number of soil samples collected during the Test Pit and Geotechnical sampling events. **Table 4-2** shows each of these soil sampling stations (CT-, WR-, GT-, and BH-) and their associated station description along with a star (*) under the Non-asbestos Analysis by Phase/Event when these samples were collected and analyzed for geotechnical index testing. Samples collected and analyzed for geotechnical index testing are not included in the nature and extent discussions in this report, and therefore, are not presented on the figures. The sample locations and geotechnical testing results are presented in the *Kootenai Development Impoundment Dam (KDID) Geotechnical and Hydrogeological Investigation Report* (MWH, 2015c).

Samples were collected in accordance with the *Work Plan for Geotechnical Characterization in Support of Creek Diversions at Libby Superfund Site OU3 Revision 2* (MWH, 2014a).

Soil samples collected for geotechnical analysis were picked up by Pioneer Technical Services, Inc. (Pioneer). Pioneer performed all geotechnical analysis by ASTM standards at their facility in Bozeman, MT.

Detailed information on the Geotechnical Test Pit effort including all associated field documentation and conclusions can be found in the *Kootenai Development Impoundment Dam (KDID) Geotechnical and Hydrogeological Investigation Report* (MWH, 2015c).

4.9.2 Investigation of the Kootenai Development Impoundment Dam (KDID) (2014) - Investigation Activities

A geotechnical investigation of the KDID and the Former Mine Area was conducted in 2014 under the oversight of MDEQ. The purpose of the investigation was to collect needed geotechnical, geological, and hydrogeological data that will be used for various stability, seepage, and geologic analytical models, which are collectively referred to as “Dam and Slope Stability Engineering”. The MDEQ, with assistance from Montana Department of Natural Resources and Conservation (MDNRC), is the lead reviewer for all Dam and Slope Stability Engineering work within the OU3 Study Area. The EPA is the lead agency and primary reviewer overseeing the CERCLA program at the OU3 Study Area. The EPA will coordinate with MDEQ on the state-led Dam and Slope Stability program and provide secondary review. The Dam and Slope Stability process has been integrated with the OU3 Study Area CERCLA RI/FS process in an effort to coordinate the work related to the dam with the CERCLA program. For example, erosion control methods that may be included in the Dam and Slope Stability remedy could also benefit water quality and should be considered in the CERCLA FS.

The scope of the Dam and Slope Stability process included KDID related issues, slope stability, erosion control, water management, and other mine closure related tasks. The Dam and Slope Stability evaluation will also balance KDID considerations for dam safety, slope stability, erosion control, and water management with the overall CERCLA objectives to protect human health and the environment.

Data collected from the 2014 investigation will be used in the future to develop a conceptual geotechnical and hydrological model with respect to the stratigraphy, engineering properties of the subsurface material, and the groundwater pressures within the KDID as part of the Dam and Slope Stability process. The investigation program consisted of drilling, field logging and evaluation, and geotechnical sampling of 13 boreholes. Boreholes were drilled in the area of the KDID for the purposes of evaluating the subsurface geotechnical and/or geologic conditions, performing in-situ testing, collecting geotechnical soil samples, and installing PVC standpipe piezometers. Vibrating wire piezometers also were installed in the PVC standpipe piezometers to collect groundwater pore pressure and temperature data.

Geotechnical testing was performed on 73 unique samples, which included:

- 28 SPT samples (retained in plastic baggies),
- 24 Mod Cal tube samples (retained in a brass or steel 6 inch tube),
- 7 Shelby Tube samples (retained in thin-walled Shelby Tube), and
- 14 Grab Samples from the recovered Sonic Core.

The following testing methods and quantities were performed as part of this program (ASTM, 2014):

- Natural Moisture Content Tests (ASTM D2216); *48 samples*
- Particle Size Analysis – Gradation Tests (ASTM D6913); *29 samples*
- Particle Size Analysis – Gradation with Hydrometer Tests (ASTM D422); *33 samples*
- Atterberg Limit Tests (ASTM D4318); *32 samples*
- Specific Gravity (ASTM D854); *7 samples*
- Density (ASTM 2937); *22 samples*
- Moisture Content and Density (ASTM D2216 & 2937); *21 samples*
- Triaxial Shear - Unconsolidated, Undrained (ASTM D2850); *6 samples*
- Consolidation Test (ASTM D2435); *5 samples*

Based on the results, samples were classified according to ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (USCS).

Table 4-1 outlines the number of soil samples collected in the KDID Investigation. **Table 4-2** provides the soil sampling locations by station ID, station description, and analyses conducted for soil samples collected in the KDID Investigation. Borehole sample locations that were analyzed for geotechnical characteristics are presented on **Figure 2-4b** inset sample IDs beginning with BH.

Samples were collected in accordance with the *Sampling and Analysis Plan / Quality Assurance Plan Geotechnical and Hydrogeological Investigation of the KDID* (MWH, 2014b).

Soil samples collected for geotechnical analysis were picked up by Pioneer Technical Services, Inc. (Pioneer). Pioneer performed all geotechnical analysis by ASTM standards at their facility in Bozeman, MT.

Detailed information on the KDID Investigation effort including all associated field documentation and conclusions can be found in the *Kootenai Development Impoundment Dam (KDID) Geotechnical and Hydrogeological Investigation Report* (MWH, 2015a). Results of the 2014 KDID investigation will be incorporated into the Dam and Slope Stability process and potentially expanded-upon in the CERCLA FS.

4.10 AQUATIC TOXICITY TESTS

The OU3 Study Area-specific toxicity tests provide information on the response of receptors that are exposed to OU3 Study Area environmental media in which they live or to which they are otherwise exposed. This may be done either in the field, which is most representative of field exposures, or in the laboratory using field exposure media collected from the OU3 Study Area. In the toxicity tests, test organisms are exposed to OU3 Study Area media containing LAA and measurements are made of organism endpoint responses to assess whether exposures are having an adverse impact on the receptor.

In the OU3 Study Area, two toxicity tests were conducted as part of the Phase II sampling program to evaluate the effect of fish and benthic invertebrate exposure to OU3 Study Area surface water

and sediment, respectively. An amphibian laboratory toxicity test was conducted as part of the Phase V Part B sampling program to evaluate if exposure of amphibians to LAA in sediment from the OU3 Study Area would result in adverse effects. In addition, in-stream (field) fish toxicity studies were conducted as part of the Phase V Part B sampling program to evaluate effects of exposure to fish (trout eggs or fry) to LAA in OU3 Study Area waters as compared to reference streams. The following sections summarize the study design of each toxicity test.

4.10.1 Trout Surface Water Toxicity Bioassay – Investigation Activities

The objective of this toxicity test was to evaluate in the laboratory the effect of fish exposure to LAA in the OU3 Study Area surface water. This test was conducted with newly-hatched larval (sac fry) rainbow trout (*Oncorhynchus mykiss*) under static renewal conditions for an exposure duration of six weeks. Survival, behavior, and growth were observed during the exposure period, and the histopathology of the fish was examined at the end of the study.

Because the primary focus of this test was on evaluating the potential toxicity of LAA in surface water to rainbow trout fry, the water used in the test was selected by monitoring the levels of LAA in OU3 Study Area waters in 2008, and choosing a time and place that was believed to be near the high-end of the observed range of LAA concentrations to collect surface water for use in the toxicity test. Based on a real-time review of the surface water concentrations in samples collected as part of the Phase II Part A sampling program (refer to **Section 4.2.2**), the tailings impoundment (station TP) was selected for evaluation in the OU3 Study Area-specific surface water toxicity test. Surface water for use in the toxicity test was collected from the tailings impoundment on May 8, 2008. Water was shipped to Parametrix Environmental Research Laboratory (PERL) in Albany, Oregon for use in the toxicity tests.

Before performing the toxicity tests, a pilot-scale study was conducted to evaluate if the aquarium water circulation system was sufficient to keep LAA fibers suspended in the test waters, thus confirming the homogeneity of exposure solution. As part of this study, triplicate samples were collected from the top and bottom third of the water column in the aquarium and samples were sent to the EMSL laboratory in Libby, Montana for rapid-turnaround analysis of LAA by TEM. The results from this pilot-scale study showed that there was no statistically significant difference, based on the Poisson ratio comparison test (Nelson, 1982), between water samples collected from the top of the aquarium and the bottom of the aquarium. This indicated that the water circulation system used in the aquarium was effective in confirming that the LAA in the water was well-mixed. Based on these results, the full-scale surface water toxicity test was initiated on May 22, 2008.

The OU3 Study Area surface water was used to prepare a series of test dilutions as follows: 100% (undiluted OU3 Study Area water), 10%, 1%, 0.1%, 0.01%, 0.001%, 0% (laboratory control water). At the test initiation, samples of the undiluted OU3 Study Area surface water were collected and sent to the EMSL laboratory in Libby, Montana laboratory for analysis of LAA and to ELI for analysis of metals/metalloids. During the larval stage, water was changed once every 10 days, and after swim up once every 3 days, for a total of seven “cycles.” For each round of static renewal, one composite water sample of each test dilution was collected shortly after the start of each renewal cycle, and one composite was collected at the end of the cycle. Samples from Cycle #1, Cycle #2, Cycle #4, and Cycle #7 were sent to the EMSL laboratory in Libby, Montana laboratory for the analysis of LAA by TEM, other water samples were archived at PERL.

4.10.2 Fiber Loss Pilot Washing Study – Investigation Activities

Problems with the above fish toxicity study resulted in a fiber loss washing pilot study to attempt to explain the LAA fiber loss issues observed. This pilot study was intended to evaluate the hypothesis that LAA fibers had adhered to a bio-film that was present in the mixing carboy and test aquaria walls. The pilot-study findings suggested the following:

- There was a loss of fibers from the water in the sample bottles. This loss could be accounted for by calculating the total amount of LAA in the bottles (in the water and on the bottle wall) and dividing by the volume of water in the bottle.
- There was a time-dependent loss of free fibers in the carboy used to hold the OU3 Study Area water sample, with the loss beginning to be apparent sometime after the start of Cycle #2 (day 11 of the toxicity test).
- There was a clear loss of fibers in the aquaria during each cycle that could not be attributed to a loss in the sample bottle.

The reason for the time-dependent loss of fibers in the carboy, the aquaria, and the sample bottles is not certain. However, the release of fibers in the sample bottles by ozonation and sonication suggests that a microbial growth may be occurring that tends to clump fibers together and ultimately binds the fibers to the walls of the container vessel. Thus, trout exposures in the toxicity tests likely diminished substantially as the test progressed and the lack of adverse effects in the study may be due to a lack of exposure and not representative of the true potential toxicity (see discussion in **Section 7.3.2**).

Toxicity tests were conducted in accordance with the *Phase II Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site Part C: Ecological Data* (EPA, 2008d). The toxicity test design and results are provided in detail in the *Toxicity of Asbestos in Waters from the Libby Superfund Site Operable Unit 3 (OU3) to Rainbow Trout (Oncorhynchus mykiss)* (Parametrix, 2009b) and the results are summarized in **Section 5.0** of this report.

4.10.3 Laboratory Aquatic Invertebrate Sediment Toxicity – Investigation Activities

The OU3 Study Area sediments were tested for toxicity in the laboratory using the amphipod *Hyalella azteca* in a 42-day test (EPA, 2000b; Test Method 100.4) for measuring the effects of sediment associated LAA and non-asbestos constituents on survival, growth, and reproduction. Sediments also were tested for toxicity to the midge *Chironomus tentans* using the life-cycle test (EPA, 2000b; Test Method 100.5) for measuring effects on survival, growth, and reproduction. The sediments used in these tests were selected at the high-end of the observed range of LAA sediment concentrations in OU3 Study Area streams and ponds. Based on a review of LAA results for sediment samples collected in Phase I and Phase II sampling programs (refer to **Sections 4.4.1** and **4.4.2**), two OU3 Study Area locations (CC-1 and TP-TOE2) were selected for evaluation in the OU3 Study Area -specific sediment toxicity test. In addition, sediments from the two offsite reference locations (BTT-R1 and NSY-R1) also were evaluated to provide an OU3 Study Area specific frame of reference for interpreting the results. See **Figure 4-3a** sample locations. Sediments for use in the toxicity tests were collected from October 14 through 17, 2008, and shipped to PERL in Albany, Oregon. Aliquots of each sediment sample were also submitted for analysis of LAA and metals/metalloids. The sediment toxicity tests were initiated on November 13 and 14, 2008, for *Hyalella* and *Chironomid*, respectively.

Toxicity tests were conducted in accordance with the *Phase I Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site* (EPA, 2007b) and *Phase II Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site Part C: Ecological Data* (EPA, 2008d). As part of the *Hyalella* toxicity test, a pore water pilot study was also conducted to quantify LAA levels within the sediment pore water of each test material at Day 0 (study initiation) and at Day 28 (at the termination of the study portion of the test). Five replicates per treatment were fitted with a suction lysimeter, which collected a 20 mL of pore water. Pore water samples from Day 0 were sent to the EMSL laboratory in Libby and samples from Day 28 were sent to Hygeia Laboratories in Sierra Madre, California for the analysis of LAA by TEM.

Detailed results of the 2008 OU3 Study Area sediment toxicity tests are summarized in *Toxicity of Libby Asbestos Superfund Site Operable Unit 3 (OU3) Sediments to the Freshwater Amphipod, Hyalella Azteca* and *Toxicity of Libby Asbestos Superfund Site Operable Unit 3 (OU3) Sediments to The Midge, Chironomus Tentans* (Parametrix, 2009c and 2009d) and the results are summarized in **Section 5.0** of this report.

4.10.4 Laboratory Amphibian Sediment Toxicity Test – Investigation Activities

The objective of the amphibian laboratory toxicity test was to establish if exposure of amphibians to LAA in the laboratory using sediment from the OU3 Study Area would result in adverse effects on survival, growth, or metamorphosis. Amphibians may be exposed to LAA in the aquatic environment both in water and sediment. This investigation focused on the evaluation of LAA exposures in sediment because previous attempts at surface water toxicity tests have shown that it is very difficult to maintain exposure conditions for LAA in surface water.

The assessment endpoints for the amphibian toxicity test were survival, growth, and metamorphosis. Reproduction was considered as a potential endpoint, but the length of time required to assess this endpoint (i.e., 5-6 additional months of exposure), and resources needed to complete a full reproduction study were decided to be impractical to implement. Potential effects on presumptive gonad tissue were proposed as an indirect way to evaluate the reproductive endpoint.

The goal was to expose organisms to the maximum sediment concentrations of LAA in the OU3 Study Area, prior to conducting the toxicity test, sediment was collected from the tailings impoundment (TP-TOE2) and Carney Creek (CC-1) (refer to **Figure 4-3a)**; these two locations have historically and consistently had some of the highest measured LAA concentrations in sediment at the mine). For each station, three “lots” of sediment were collected. Five replicate samples of each lot were prepared at the Troy SPF and analyzed by PLM-VE at the EMSL laboratory in Libby, Montana.

Toxicity tests were conducted in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan Operable Unit 3, Libby Asbestos Superfund Site Phase V Part B: 2012 Ecological Investigations* (EPA, 2013a). The toxicity test design and results are provided in detail in the *Amphibian Complete Metamorphosis Exposure Study* (Golder, 2013b) and the results are summarized in **Section 5.0** of this report.

4.10.5 Phase V, Part B In-Stream Field Fish Toxicity Studies (2012 and 2013) – Investigation Activities

The objective of this study was two parts:

1. To expose early life stage cutthroat trout eggs to LAA in OU3 Study Area pore water to establish if the exposure resulted in higher toxicity for several endpoints relative to that observed in reference streams. In this study, trout eggs were placed in WVB chambers buried within streambed gravel in both OU3 Study Area and reference streams to establish if there was a significant difference in hatching success, alevin survival and alevin growth endpoints.
2. To expose juvenile cutthroat trout to LAA in OU3 Study Area surface water to establish if there was a significant difference in growth or survival relative to that of reference streams. In this study, juvenile (3 – 5 inch) trout were place in cages in both the OU3 Study Area and reference streams to establish if there was a significant difference in survival and growth endpoints.

For the OU3 Study Area egg pore water toxicity study, six WVBs were placed in LRC, two boxes each at stations LRC-2, LRC-4, and LRC-5 (refer to **Figure 4-1a**). Six boxes also were placed into the gravel of reference streams, three boxes each at URC station URC-2 and in Noisy Creek (NSY) (refer to **Figure 4-1a**). The creek locations and burial treatment for the WVBs were meant to approximate exposures that could occur in a natural redd (fish spawning nest). Temperature controlled refrigerator / negative control eggs were also maintained in WVBs at an offsite laboratory as control organisms. For the juvenile trout surface water toxicity study, the test conditions were designed to mimic the exposure of young fish to LAA in a natural stream setting. As with the egg toxicity study, two floating juvenile trout cages were placed at each of the same three LRC locations for a total of six OU3 Study Area replicates; three replicate cages also were placed at each of the same two reference creeks. External examinations of all study specimens (unhatched egg, alevins, and juvenile trout) was conducted by a board certified pathologist.

Toxicity tests were conducted in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan Operable Unit 3, Libby Asbestos Superfund Site Phase V Part B: 2012 Ecological Investigations* (EPA, 2013a).

Water samples from OU3 Study Area and reference locations were analyzed for total LAA by TEM, treating the water with ozone/UV prior to analysis to remove biological material that might cause fiber clumping.

Eyed egg toxicity test results were presented and evaluated in three technical reports in the *Technical Memorandum: Eyed Egg Study. Libby Asbestos Superfund Site, Operable Unit 3,* the *Data Report: 2012 In Situ Westslope Cutthroat Trout Toxicity Studies, Operable Unit 3;* and the *Data Report: 2013 In Situ Westslope Cutthroat Trout Toxicity Study .Operable Unit 3* (SRC, 2013; Golder, 2013a and 2014a). The juvenile trout toxicity study is reported in the same data report as the 2012 eyed egg study. The results of these studies are summarized in **Section 5.0** of this report.

4.11 AQUATIC COMMUNITY AND HABITAT STUDIES

Another line of evidence that is often relied upon in the evaluation of ecological risks is direct observations of ecological community and habitat metrics. These observations seek to establish

whether any receptor population has unusual numbers of individuals (either lower or higher than expected), or whether the diversity (number of different species) of a particular category of receptors (e.g., plants, fish, small mammals, birds) is different in the OU3 Study Area than expected (relative to a selected reference area).

In the OU3 Study Area, direct observations (surveys) of the fish and aquatic invertebrate community and stream habitat were made during the 2008 and 2009 field seasons as part of the Phase III sampling program. In addition, a stream pool classification evaluation was performed in 2011 as part of the Phase IV Part B sampling program. A resident trout lesion study and an amphibian field study were conducted in 2012 as part of the Phase V sampling program. The following sections summarize the investigation activities for each study. Results are summarized in **Section 5.0** of this report.

4.11.1 Fish Community – Investigation Activities

Surveys of fish density and diversity were performed in October of 2008 and September 2009. A total of nine stream locations were evaluated, including two in URC (URC-1A and URC-2), four in LRC (LRC-1, LRC-2, LRC-3, and LRC-5), one location downstream of the tailings impoundment (TP-TOE2) and at two offsite reference locations (BTT-R1 and NSY-R1) (refer to **Figure 4-1a**).

In 2008, fish of two size classes (<65mm and >65 mm - <100 mm) were collected using electroshocking equipment. Multiple passes of electroshocking were performed at each sampling location. In 2009, minnow traps were used in addition to the electroshocking passes in an effort to increase the effectiveness of capturing fish in the smaller of the two size classes. Length, weight, and species type were recorded for each fish collected.

Surveys were completed in accordance with the *Remedial Investigation for Operable Unit 3 Libby Asbestos Superfund Site Phase III Sampling and Analysis Plan* (EPA, 2009c). Detailed information on the fish community sampling methods and findings is provided in *Final Data Report: Remedial Investigation, Operable Unit 3 of the Libby Asbestos Superfund Site, Phase II, Part C: Autumn 2008 Aquatic Data Collection Program* and *Final Data Report: Remedial Investigation, Operable Unit 3 of the Libby Asbestos Superfund Site, Phase III: Autumn 2009 Aquatic Data Collection Program* (Parametrix, 2009a and 2010) and the results are summarized in **Section 5.0** of this report.

4.11.2 Benthic Macroinvertebrate Community – Investigation Activities

Surveys of benthic macroinvertebrate (BMI) density and diversity were performed in 2008 and 2009 at the same OU3 Study Area and reference sampling stations where fish surveys were performed. At each location, BMI samples were collected using two different protocols, EPA's Rapid Bioassessment Protocol and US Forest Service Surber Protocol. For each sample, invertebrates were identified to the genus level and the relative abundance of each taxon was reported.

Surveys were completed in accordance with the *Remedial Investigation for Operable Unit 3 Libby Asbestos Superfund Site Phase III Sampling and Analysis Plan* (EPA, 2009c). Detailed information on the BMI sampling efforts are provided by Parametrix (2009a and 2010) and the results are summarized in **Section 5.0** of this report.

4.11.3 Habitat Assessment – Investigation Activities

Because variations in habitat can contribute to differences in aquatic populations between stations, a habitat assessment was completed at each aquatic community survey location using procedures from the EPA RBP method (Plafkin *et al.*, 1989; Barbour *et al.*, 1999). Ten alternative measures of habitat quality were combined to yield an overall habitat quality score (HQS) for each sampling location that reflects overall habitat quality. For each sampling location, a relative score (percent of reference) was also calculated. This relative score indicates how closely habitat quality was matched to the reference station.

Surveys were completed in accordance with the *Remedial Investigation for Operable Unit 3 Libby Asbestos Superfund Site Phase III Sampling and Analysis Plan* (EPA, 2009c). Detailed information on the Habitat Assessment is provided in Parametrix 2009a and 2010 and the results are summarized in **Section 5.0** of this report.

4.11.4 Stream Pool Assessment – Investigation Activities

In 2011, the Phase IV Part B data collection efforts included a field investigation to better characterize the habitat suitability of OU3 Study Area and reference streams for fish. The study included the collection of stream pool characteristics in OU3 Study Area and reference streams to provide information on habitat factors that might influence fish population abundances. In small streams, the high temperature in water during the summer is an important factor in determining habitat suitability for fish. Access to deeper pools, where water is cooler, is critical for fish to escape excess heat in the summer, and also to prevent freezing in the winter. Although stream habitat and surface water temperature data were collected in earlier investigations, additional surface water temperature data and more detailed characterization data of the in-stream pools were needed to utilize habitat suitability index (HSI) models for cutthroat and rainbow trout to evaluate the suitability of Rainy Creek to support and sustain fish populations (Raleigh *et al.,* 1984) and to assess whether habitat factors were influencing fish populations in Rainy Creek. The Phase IV Part B habitat data were collected to provide information for HSI model variables V_1 (average maximum water temperature) and V_{15} (pool class rating).

The stream pool assessment was conducted in accordance with the *Phase IV Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site Part B: 2011 Surface Water Study* (EPA, 2011a). Detailed information on the Stream Pool Assessment is provided in the *Final Data Report: OU3 and Reference Stream Pool Assessment (Size, Temperature), 2011, Libby, Superfund Site, OU3, Lincoln County, Montana (*Anchor QEA, LLC, 2012*)* and the results are summarized in **Section 5.0** of this report.

4.11.5 Phase V, Part B Resident Trout Study – Investigation Activities

The objective of this study was to establish whether the frequency and severity of lesions or abnormalities in fish resident in LRC is higher than for fish from reference creeks. Key study design features of the resident trout study are summarized below.

Resident trout in two size classes (<65 mm and > 65 mm - < 100 mm) were sought for the lesion study; a total of 20 fish (10 in each size class) from LRC and 20 fish from each of two reference streams, for a total of 60 fish sought in all the streams. Due to difficulties in 2008 and 2009 in capturing the younger size class fish in LRC (none were obtained in either year) the capture of the resident trout from all streams was temporally advanced from September/October to early

August in the event the young fish were growing out of the small size class due to the warmer creek temperatures in LRC.

Resident trout in both of the size classes targeted were captured using electro-shocking at LRC, URC, and NSY in early August 2012 (between August 1 and 6, 2012). Minnow traps were also deployed, but were largely unsuccessful in capturing any fish. Within LRC, fish in both size classes were collected at multiple stations, including locations where previous population studies have been performed. Sampling was conducted at stations LRC-2, LRC-3, LRC-4, LRC-5, and TP-TOE2 and at reference stations URC-2, URC-1A, and NSY-R1 (refer to **Figure 4-1a**).

Captured fish were examined in the field for external parasites or other external gross abnormalities. Lengths of collected fish were measured in the field, from the tip of the snout to the tip of the top lobe of the caudal fin (to the nearest mm) and recorded in the field notebook and forms. Only cutthroat, rainbow, and cutbow trout within the two size classes were kept; any other fish were released. Collected fish were kept in plastic containers filled with cold water from their respective creek until transported to the offsite laboratory for processing and preservation. Processing in the offsite laboratory included: fish euthanization, recording the weight of each fish, verification of field collected length measurement, and preserving the organism for external examination by a board certified pathologist.

Captured fish were euthanized, preserved in 10% neutral buffered formalin, and shipped to Northwest ZooPath pathology laboratory in Monroe, Washington for external examinations followed by histological examinations on a subset of the specimens. External examinations focused on abnormalities present on the head, fins, skin, and gills. Particular attention was paid to any abnormalities of the gills and lateral line. If tumors or other anomalies were identified, these tumors/abnormalities were excised, sectioned, stained, and examined microscopically by the pathologist.

Surface water sample collection was not a part of the resident trout lesion study design. This is because a single water sample collected at the time of fish collection would not reflect the concentrations to which the fish were exposed over their lifespan.

Samples were collected and processed in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan Operable Unit 3, Libby Asbestos Superfund Site Phase V Part B: 2012 Ecological Investigations* (EPA, 2012d). Detailed study results are presented in the *Data Report: 2012 Resident Trout Study* (Golder, 2013c) and the results are summarized in **Section 5.0** of this report.

4.11.6 Phase V, Part B Amphibian Field Study – Investigation Activities

The objective of this study was to establish if there was a discernible difference among the various amphibian developmental stages present in the OU3 Study Area ponds relative to those occurring in reference ponds as well as to establish whether there was a higher incidence of lesions or abnormalities. Key study design features of the amphibian field study are summarized below.

Sampling Design:

Study Areas. A field reconnaissance was performed in March 2012 to decide upon candidate locations for collecting developing amphibians. OU3 Study Areas selected included: Carney Creek Pond, Fleetwood Creek Pond, Mill Pond, and the tailings impoundment (Golder, 2012)

(refer to **Figure 4-1a**). Reference areas selected included: Bobtail Pond, Banana Lake, and Tepee Pond 1 (Golder, 2012) (refer to **Figure 4-1a**). Prior to use as a reference location, sediment samples were collected from each candidate reference pond for analysis of LAA and non-asbestos constituents to verify that the ponds were not contaminated. Candidate reference areas included: Bobtail Pond 1, Bobtail Pond 2, Banana Lake, Shrieber Lake, Tepee Pond 1, and Tepee Pond 2. Reference areas were selected based on the analytical results and general habitat similarity to the OU3 Study Area ponds.

Environmental Characterization. The amphibian field study was conducted in accordance with the Phase V Part B SAP/QAPP (EPA, 2012d). During the study, the field teams visited the onsite and reference locations twice a week to check if specimens from each developmental window were available. The exact time that amphibians breed and their eggs begin development depends on many environmental factors, especially temperature. During each of the bi-weekly visits, pond water temperature was measured and recorded.

Surface water samples were collected weekly once egg masses were estimated to be present starting on May 24, 2012 and ending on August 31, 2012. Surface water sampling was performed in accordance with the OU3 Study Area-specific SOP No. 3, *Surface Water Sampling*, using the direct sampling methods. Water samples were submitted for analysis of LAA by TEM.

Because sediments are not expected to vary substantially over time, two samples of sediment were collected for analysis of LAA, the first sample near the beginning of the study (May 5, 2012) and the second sample near the end of the study (October 9, 2012). Sediment sampling was performed in accordance with the OU3 Study Area-specific SOP No. 5, *Sediment Sampling*. In brief, at each pond surface sediment was collected from the pond edge at multiple points around the pond and composited into a single sample. After being processed (dried, sieved, ground) by the Troy sample processing facility, sediment samples were submitted for analysis of LAA by PLM-VE by the EMSL laboratory in Libby, MT as detailed in SOP SRC-LIBBY-03. There were not any coarse fractions for sediment samples. Non-asbestos constituent analyses of sediment were performed by Energy Laboratory in Billings, MT.

Amphibian Developmental Stages. Because information on the potential effects of LAA on amphibian development is lacking in the scientific literature, the field study evaluated the full developmental period from egg mass through metamorphosis. The frequency of specimen collection from each developmental window (refer to below), was dependent upon meteorological conditions and specimen availability. Developmental stages were stratified into four windows, as follows:

- egg mass,
- embryo-larval (Gosner stages 21-25),
- hind limb development completion (Gosner stages 37-40), and
- metamorphic completion (post-climax) (Gosner stage 46).

Amphibian Measurement Endpoints. Measurement endpoints for each developmental window included external physical examination for abnormalities in all specimens and all life stages, regardless of species. In addition, necropsy was performed in all newly metamorphosed specimens. Organism weights and lengths were also measured for each

lifestage. Histopathology was then performed on the metamorphosed specimens by a board certified pathologist

Samples were collected in accordance with the *Sampling and Analysis Plan/Quality Assurance Project Plan Operable Unit 3, Libby Asbestos Superfund Site Phase V Part B: 2012 Ecological Investigations* (EPA, 2012d). Detailed results of the amphibian field study are presented in *Data Report: 2012 Field Collection, Examination and Pathology of Amphibian Species* (Golder, 2014b) and the results are summarized in **Section 5.0** of this report.

4.12 SMALL MAMMAL COMMUNITY ASSESSMENT

Direct observations of the ecological community at a site are often used as one line of evidence in the assessment of potential ecological risks. In the case of small mammals, because there are no accurate and representative data on measures of asbestos exposure in wild small mammals the study was designed to sample multiple small mammal species to evaluate organism health and determine whether a higher incidence of lesion frequency and severity at the OU3 Study Area was discernible relative to small mammal species captured at reference locations. Small mammal species at the OU3 Study Area were captured at locations reported to have the highest duff material concentrations of LAA on the OU3 Study Area. Targeted small mammal species included the deer mouse and chipmunk.

Samples were collected in accordance with the *Remedial Investigation for Operable Unit 3 Libby Asbestos Superfund Site Phase III Sampling and Analysis Plan* (EPA, 2009c). Details of the field collection efforts for the small mammal survey, including all field documentation, are summarized in the final data report, *Summer 2009 Small Mammal Data Collection Program* (Golder, 2010).

4.13 BIRD COMMUNITY ASSESSMENT

A bird community literature-based evaluation was conducted as part of the *Final Asbestos BERA* (EPA, 2014a) and the *Final Non-Asbestos BERA (*CDM Smith, 2013c). There were 175 birds identified as residing all or part of the year within the OU3 Study Area and 17 of these birds are listed as species of concern to the State of Montana (refer to **Table D-7** of **Appendix D**). However, not all of these 17 birds are equally likely to occur within the OU3 Study Area. Based on an evaluation of where the birds were reported within Lincoln County, the following two birds are considered to be the most likely to occur in the OU3 Study Area:

- Flammulated Owl (*Otus flammeolus*)
- Northern Goshawk (*Accipiter gentilis*)

Results of the evaluation were utilized in the *Final Asbestos BERA* (EPA, 2014a) and *Final Non-Asbestos BERA* (CDM Smith, 2013c) which are discussed in further detail in **Section 7.0**.

4.14 FISH AND GAME TISSUE COLLECTION

In 2012, a study, referred to as the *Fish and Game Tissue Assessment*, was conducted to investigate LAA tissue burdens in fish and large game collected from the OU3 Study Area. All samples generated as part of the investigation were collected, documented, and handled in accordance with the*. Sampling and Analysis Plan/Quality Assurance Project Plan: Fish and Game Tissue Assessment. Libby Asbestos Site, Operable Unit 4* (EPA, 2012j).

The purpose of the study was to collect data on tissue burdens of LAA that could accumulate in large game and fish tissue to evaluate two potential human ingestion exposure scenarios:

- **Ingestion of Game.** One exposure scenario is the ingestion of edible tissue from hunted game that forage at the OU3 Study Area. Large game, including deer and elk, have been observed at the OU3 Study Area and may be exposed to LAA in a variety of potential exposure media. It is possible that these animals may have accumulated LAA in their tissues as a result of these exposures.
- **Ingestion of Fish.** Large fish occur in the Mill Pond and were collected to provide data on the ingestion of LAA in edible fish tissue (fillets) from fish caught from local streams and ponds that contain LAA.

A total of two rainbow trout, three cutbow trout, and one cutthroat trout along with one mule deer were collected in the OU3 Study Area and tissue samples were analyzed by TEM (see EPA, 2012j for analysis methodology).

Detailed information on the study design and collection methods are presented in the *Data Summary Report: Fish and Game Tissue Assessment* (CDM Smith, 2013d) and the results are summarized in **Section 5.0** of this report.

5 NATURE AND EXTENT OF CONTAMINATION

The following subsections present the nature and extent of non-asbestos constituents and LAA detected in the various media sampled in the OU3 Study Area as part of the RI. For the purposes of the nature and extent discussion for these constituents (as well as the fate and transport in **Section 6.0**), the following primary media definitions (EPA, 2015g) are used:

- **Mine Waste:** Soil, rock, and other earthen materials excavated from a mine and slimes, tailings, dusts, sludges, or other waste products from the crushing, cleaning, milling, or beneficiation of ores.
- **Soil:** The unconsolidated mineral or organic matter on the surface of the Earth that has been subjected to, and shows effects of, environmental factors of: climate (including water and temperature effects), and macro- and microorganisms, conditioned by relief, acting on parent material over a period of time. Soil excludes materials defined as mine waste, bark, duff, or ash.
- **Bark:** The tough outer covering of the woody stems and roots of trees, shrubs, and other woody plants outside the vascular cambium (note that only LAA analyses were performed for bark samples).
- **Duff:** Partially- to fully-decomposed bark, twigs, needles, leaves, grasses, and other vegetation and the layer of litter that occurs on top of the mineral soil in forested areas (note that only LAA analyses were performed for duff samples).
- **Ash:** The solid residue left when combustible material is thoroughly burned (note that only LAA analyses were performed for ash samples).
- **Surface water:** Any waters on the Earth's surface including, but not limited to, streams, lakes, ponds, and reservoirs; and irrigation and drainage systems discharging directly into a stream, lake, pond, reservoir, or other surface water. Water bodies used solely for treating, transporting, or impounding pollutants shall not be considered surface water.
- **Groundwater:** Water occupying the voids within a geologic stratum and within the zone of saturation.

Other media that were sampled, but were not specifically defined in EPA, 2015g, include bedrock and outcrops (synonymous with bedrock), cover/fill material and road material (included with “soil” herein), glacial materials and alluvium (included with “soil” herein), sediment pore water (i.e., water occupying the spaces between sediment particles in an aqueous environment), tissue, and air. It is important to note that comparisons to the various benchmarks and reference levels made throughout this section are intended for describing the nature and extent of constituents that may be attributable to historical activities related to mining, milling, and activities ancillary to mining and milling that occurred in the OU3 Study Area. These comparisons should not be misinterpreted as equating to the level or extent of actual risk posed to potential receptors in the OU3 Study Area, which are discussed later in **Section 7.0**. Likewise, the benchmarks and reference levels used herein do not establish the chemical-specific Applicable or Relevant and Appropriate Requirements (ARARs) for the OU3 Study Area. The ARARs will be established in the Record of Decision (ROD).

In addition, it should be noted that naturally occurring materials and erosional processes that were unrelated to prior anthropogenic activities have likely contributed to both non-asbestos and LAA levels in various media in and around the OU3 Study Area. Although OU3 Study Area-specific background levels have not been established for the various media of concern, where applicable,

reference levels that were collected from areas that were presumed to have not been impacted by historical mine-related activities were utilized for comparison purposes herein. The subject of naturally occurring materials is discussed in **Section 2.11.1.**

5.1 NATURE AND EXTENT OF NON-ASBESTOS CONSTITUENTS

The nature and extent of non-asbestos constituents are presented by media below. Because many of the analyzed constituents are naturally occurring (e.g., metals/metalloids), detected concentrations are compared to various established benchmarks and reference levels in an attempt to identify constituent concentrations that may be attributable to historical mining activities or remnant mine wastes. Where applicable, these comparison benchmarks and reference levels for the non-asbestos constituents include the following:

- Montana Department of Environmental Quality Circular DEQ-7 numeric water quality standards for Montana's surface and groundwaters (http://deq.mt.gov/Portals/112/Water/WQPB/Standards/PDF/DEQ7/FinalApprovedDEQ7.pdf).
- Numeric surface water quality standards established under the Administrative Rules of the State of Montana (ARM) 17.30.601 through 17.30.670 to protect beneficial water uses (http://www.mtrules.org/gateway/Subchapterhome.asp?scn=17%2E30%2E6).
- Background threshold concentrations of inorganic constituents in Montana surface soils (https://deq.mt.gov/Land/statesuperfund/background).
- Constituent concentrations at reference locations presumed to be not impacted by historical mining activities (e.g., locations upstream or outside of areas disturbed by mining activities). As discussed below, reference locations were sampled for non-asbestos constituents in the following media: surface water, sediment, and soil.

Independent of this nature and extent evaluation, all detected non-asbestos constituents were further evaluated in the EPA-prepared risk assessments for non-asbestos constituents that are summarized in **Section 7.0**. A complete data summary for all RI non-asbestos data is included in **Appendix E.**

5.1.1 Non-Asbestos Data Considerations

5.1.1.1 Non-Asbestos Reference Data

Various OU3 Study Area RI activities included sampling environmental media at reference locations that were presumed to not be impacted by previous mining activities or the presence of mine waste. The analytical results from the reference-location samples are compared herein with the analytical results from the samples collected in the OU3 Study Area as a line-of-evidence to identify the non-asbestos constituent concentrations in the OU3 Study Area that may be elevated due to natural conditions specific to the Former Mine Area and/or as a result of previous mining activities or the presence of mine waste (i.e., mine-impacted). Non-asbestos reference data are available for surface water (**Section 5.1.2**), sediment (**Section 5.1.4**), and soil (**Section 5.1.5**) as discussed below in the media-specific subsections.

5.1.1.2 Non-Asbestos Data Adequacy Evaluation

The *Phase III Sampling and Analysis Plan for Operable Unit 3* (EPA, 2009) included a detailed evaluation of the adequacy of available non-asbestos data for surface water, groundwater, sediment, and soil/mine waste to determine if additional sampling was needed in the Phase III investigation to support risk management decision-making. As indicated in the *Human Health Risk Assessment for Non-Asbestos Contaminants, Operable Unit 3, Libby Superfund Site* (CDM Smith, 2013b), available non-asbestos data from the OU3 Study Area were found to be spatially and temporally representative, since multiple surface water and sediment samples were collected from each major segment of the OU3 Study Area watershed during three different times of year, and groundwater samples were collected during a two-year period from all existing functional wells in the OU3 Study Area. Statistical adequacy was evaluated by performing a conservative risk-based screen for each media. In all cases, screening-level risks were low (see EPA, 2009 for results). "Thus, it was concluded that available data for non-asbestos contaminants in surface water, groundwater, sediment, and soil/mine waste were adequate to support risk management decision-making and that no further non-asbestos contaminant sampling was needed in subsequent RI sampling programs" (CDM Smith, 2013b).

5.1.1.3 Evaluation of Non-Asbestos Analytical Quantification Limits

A limitation to comparing non-asbestos constituent concentrations to the various benchmark levels is that the analytical method-specific practical quantification limits (PQLs) are sometimes higher than the associated benchmark concentration. In other cases, there is no established benchmark level for a particular constituent. **Tables E-5a** through **E-5c** (located in **Appendix E**) include comparisons of PQLs (for surface water, groundwater, and soil/mine waste, respectively) to the associated benchmark levels for all constituents that were not detected. **Tables E-5a** through **E-5c** highlight the constituents where the mean PQL, calculated for constituents with more than one sample, is greater than the associated benchmark level. In these situations, it is not possible to know with certainty if the constituent concentration is present at concentrations greater than the associated benchmark level. However, there is no specific reason to suspect that these constituents are present at significant levels in the OU3 Study Area and they are not likely to pose a significant limitation to defining the nature and extent of non-asbestos constituents.

5.1.2 Non-Asbestos Constituents in Surface Water

Figure 4-1b depicts the locations within the OU3 Study Area and reference locations (generally outside of the OU3 Study Area) where surface water samples were collected during the Phase I, Phase II, and spring 2015 (WT-2015) sampling programs for non-asbestos analyses (note that the 2015 locations were only sampled for water chemistry and general water quality parameters). In Phase I, surface water samples were collected in October 2007 at a total of 24 locations along Carney Creek, Fleetwood Creek, and Rainy Creek, including the ponds and impoundments on these streams, as well as nearby seeps. In Phase II, surface water samples were collected at the same locations as Phase I, plus additional stations in upper Rainy Creek (URC-1A), Carney Creek pond (CC-Pond), the upper tailings pond (UTP), and in the reference areas (Noisy Creek [NSY-R1] and Bobtail Creek [BTT-R1] located outside of the OU3 Study Area). With the exception of the two reference areas, Phase II surface water samples for non-asbestos constituents were collected twice from each station, once in June 2008 and once in September 2008.

All Phase I and Phase II surface water samples were analyzed for metals and metalloids, petroleum hydrocarbons, anions, nitrogen-containing compounds, and other water quality

parameters. In addition, several selected surface water samples were analyzed for a broad suite of other constituents, including volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and selected radionuclides. **Table 5-1** shows the non-asbestos analyses that were performed for surface water samples from each location and the number of times each location was sampled. **Tables 5-2a** and **5-2b** summarize all of the analytical results for non-asbestos constituents that were detected in surface water within the OU3 Study Area and outside of the OU3 Study Area, respectively. A complete summary of the surface water analytical results (including non-detected constituents) is contained in **Appendix E**.

The nature and extent evaluation of non-asbestos constituents in surface water included the following steps:

- Comparison to Montana DEQ-7 Standards.
- Comparison to results from reference locations.
- Evaluation of spatial and temporal patterns.

5.1.2.1 Comparison with DEQ-7 Human Health Standards for Surface Water

Non-asbestos results from OU3 Study Area and reference surface water samples were compared with DEQ-7 human health standards to aid in the determination of the nature and extent of various constituents (see **Table 5-3a**). No non-asbestos constituents were detected in OU3 Study Area or reference surface water samples at concentrations that exceed their respective DEQ-7 human health standards (see **Table 5-3a**).

5.1.2.2 Comparison with DEQ-7 Aquatic Life Standards for Surface Water

Non-asbestos results from OU3 Study Area and reference surface water samples were compared with DEQ-7 aquatic life standards to aid in the determination of the nature and extent of various constituents (see **Tables 5-3a** and **5-3b**). OU3 Study Area seep locations were excluded from the DEQ-7 aquatic-life standards comparisons because these locations are not considered viable aquatic habitat in the *Non-Asbestos BERA*. However, surface water samples from locations that may be impacted by these seeps (i.e., Carney Creek) were included in this assessment.

DEQ-7 has both acute and chronic surface-water standards for aquatic life (see **Table 5-3a**). There are standards for metals in total (unfiltered) sample results with the exception of aluminum, in which case the standards are for the dissolved (filtered) sample results. No non-asbestos constituents were detected in the OU3 Study Area or reference locations at concentrations above DEQ-7 acute surface water standards for aquatic life. Non-asbestos constituents that exceeded DEQ-7 chronic surface-water standards for aquatic life at OU3 Study Area locations included iron in the September 2008 sample collected from FC-Pond, and lead (calculated based on hardness; see **Table 5-3c**) in the October 2007 sample collected from FC-Pond. The maximum iron concentration at FC-Pond was 1760 µg/L compared to the DEQ-7 chronic standard of 1000 µg/L. The maximum lead concentration at FC-Pond was 5.1 µg/L compared to the DEQ-7 chronic standard of 4 µg/L. At the reference surface water location URC-1A in Upper Rainy Creek, located within the OU3 Study Area (discussed below), copper (calculated based on hardness; see **Table 5-3b**) was detected at 16 µg/L above the DEQ-7 chronic surface-water standard of 12.7 µg/L for aquatic life in the June 2008 sample. These sample locations were upstream of the disturbed areas of the Former Mine Area.

The range of detected iron and lead concentrations in the FC-Pond samples was relatively large, and were below the DEQ-7 standard in two of the three samples collected from this location. In the three FC-Pond samples, iron concentrations ranged from 50 µg/L to 1760 µg/L, and lead concentrations ranged from 0.5 µg/L to 5.1 µg/L with two of the three samples having detectable levels. As would be expected with total metals analyses, the higher iron and lead concentrations correlate with the increased total suspended solids (TSS) concentrations in the three samples collected from FC-Pond. Potential mine-related exceedances of DEQ-7 chronic surface-water standards for aquatic life are limited to iron and lead, are inconsistent (more often below the DEQ-7 standard than above), and are not widespread in the OU3 Study Area (exceedances occurred only at the FC-Pond location). Moreover, these constituents (i.e., iron and lead) may have naturally elevated concentrations due to the mineralogy of the OU3 Study Area as described in **Section 2.11.1**.

5.1.2.3 Comparison of OU3 Study Area Surface Water Data with Reference Data

Inorganic, non-asbestos results from OU3 Study Area surface water samples were compared statistically with the inorganic, non-asbestos results from the reference locations to identify constituent concentrations that may be elevated within the OU3 Study Area relative to reference. This evaluation was performed as a line-of-evidence to identify inorganic, non-asbestos constituents that may have elevated concentrations in OU3 Study Area surface water. A description of the statistical evaluation is contained in **Appendix H**. Note that this evaluation was limited to inorganic constituents that occur naturally (e.g., metals/metalloids) because organics are likely to have anthropogenic origin both within and outside of the OU3 Study Area. Therefore, comparing organic constituent concentrations detected in the OU3 Study Area with organic constituent concentrations detected at reference locations would not help determine if the presence of organic constituents in the OU3 Study Area samples are mine-related. A discussion of organic, non-asbestos constituents detected in OU3 Study Area sediment samples is presented separately below in **Section 5.1.4.2**.

Inorganic, non-asbestos constituents that were found to have elevated concentrations relative to reference were evaluated using box-and-whisker plots to identify the surface water sampling locations, or groups of locations, where the elevated constituent concentrations were located in the OU3 Study Area. This information was used to identify the spatial distribution of the elevated inorganic, non-asbestos constituent concentrations, if possible. Note that evaluations of temporal trends are limited because most surface water locations have only been sampled two or three times for non-asbestos constituents.

Surface water reference locations (i.e., locations presumed to not be impacted by previous mining activities or existing mine wastes) include locations in Noisy Creek (NSY-R1) and Bobtail Creek (BTT-R1) (see **Table 5-2b** for off-site reference location summary data), and sample locations in Upper Rainy Creek (URC-1, URC-1A, and URC-2); see **Figure 4-1b**.

The inorganic, non-asbestos constituents in the OU3 Study Area surface water samples that were elevated compared to reference locations are listed on **Table H-2** (located in **Appendix H**). With the exception of barium, fluoride, and manganese, none of the inorganic, non-asbestos constituents listed as elevated on **Table H-2** are on the CERCLA Priority List of Hazardous Substances (ATSDR, 2015). The remainder of the inorganic, non-asbestos constituents that are elevated compared to reference locations are general water quality parameters (e.g., cations and anions), and are discussed separately below. Box-and-whisker plots of the analytical results for these constituents are depicted for all OU3 Study Area surface water sampling locations in **Appendix H**, **Attachment H-1**. The box-and-whisker plots are useful for visualizing the locations

(or groups of locations) where the inorganic, non-asbestos constituents are elevated relative to other OU3 Study Area locations, and for visualizing the range of detected concentrations at each location.

Box-and-whisker plots show that the highest concentrations of barium (both total and dissolved) generally are in the seeps along the waste rock piles (highest barium concentrations were detected at seep locations CCS-1, CCS-9, and CCS-16) and in Carney Creek location CC-2. Maximum concentrations of barium in the seeps along the waste rock piles ranged from 600 µg/L to 1,000 µg/L for both total and dissolved fractions. The maximum barium concentration at CC-2 was 700 µg/L for both total and dissolved fractions. The lowest barium concentrations were detected in the Upper Tailing Pond location (UTP; maximum concentration of 200 µg/L for both total and dissolved fractions), where concentrations were similar to reference (note that the UTP location is upgradient from where potentially mine-impacted discharges enter the Tailing Pond [e.g., Fleetwood Creek and runoff from the coarse tailings]). Barium is commonly associated with barite deposits, which occur naturally in the region.

Manganese concentrations were generally similar at most locations, except for seep location CCS-6 (maximum concentration of 360 µg/L for total and 610 µg/L for dissolved) and CCS-16 (maximum concentration of 940 µg/L for total and 980 µg/L for dissolved) where concentrations were higher. Manganese is commonly associated with biotite, pyrite, and manganese oxide minerals, which occur naturally in the region.

Fluoride concentrations were higher in Lower Rainy Creek below the KDID (including the Mill Pond) relative to the other OU3 Study Area surface water sampling locations. Fluoride concentrations in Lower Rainy Creek and the Mill Pond range from 600 µg/L to 1,100 µg/L, compared to 50 µg/L to 300 µg/L at all other surface water sampling locations. Presence of higher fluoride levels in Lower Rainy Creek may be related to fluorapatite and biotite minerals (associated with the pyroxenite bedrock) in the fine tailings pile.

Both surface water and sediment samples were collected at many of the same locations (a discussion of non-asbestos constituents in sediment is presented below in **Section 5.1.4**). A qualitative review of the surface water and sediment box-and-whisker plots indicates that the elevated barium and manganese concentrations in the surface water samples collected at seep location CCS-16 described above correlate with the barium and manganese concentrations in the sediment samples collected at the same location (i.e., barium and manganese concentrations also are elevated in the sediment samples collected at CCS-16). However, there does not appear to be a correlation between barium and manganese concentrations in surface water and sediment samples collected at CCS-1, CCS-6 and CCS-9. There also does not appear to be a clear correlation between the barium concentration detected in the surface water sample at the CC-2 location and the barium concentration in the sediment sample collected at the same location. The elevated fluoride concentrations detected in the Lower Rainy Creek surface water samples do not correlate with fluoride concentrations in the sediment samples collected at the same locations.

Several other general water quality parameters (that had elevated concentrations relative to reference locations) generally were higher in the seep locations and Carney Creek (down-gradient of the seeps), including alkalinity, bicarbonate, calcium, hardness, magnesium, phosphorous, potassium, sodium, TDS, and sulfate. These results suggest that interaction of water with the waste rock piles (which overlie the seeps that ultimately drain to Carney Creek) may be causing higher levels of inorganic, non-asbestos constituents observed in surface water in the area.

Based on the groundwater and surface water geochemistry evaluation presented in **Section 2.9**, the groundwater monitored by Wells D, E, and H may be hydraulically connected with water discharging at the seep locations. Visual comparisons of the box-and-whisker plots for the inorganic, non-asbestos constituents detected at the seep locations with the inorganic, non-asbestos constituents detected in Wells D, E, and H do not conclusively support this conceptual model (note that groundwater data are evaluated separately below in **Section 5.1.3**). This is because the relative constituent concentrations in the seep samples do not consistently correlate with the relative constituent concentrations in the groundwater samples from Wells D, E, and H. For example, some seep results correlate with groundwater results from one and sometimes two of these wells, but not the others. It does appear that the inorganic, non-asbestos constituent concentrations detected at the seeps correlate most consistently with the groundwater data from Wells E and H. Based on this qualitative comparative review, it is possible that the water discharging from the seep locations is a combination of groundwater and interflow (i.e., the lateral movement of water in the unsaturated zone that first returns to the surface or enters a stream prior to becoming groundwater).

Other possible conclusions that can be drawn from the inorganic, non-asbestos box-and-whisker plots include:

- With a few exceptions (e.g., fluoride and manganese), the concentrations of inorganic, non-asbestos constituents in surface water do not exhibit clear decreasing trends downstream in Lower Rainy Creek away from the former mined area. Decreasing trends away from the mined area would be expected if the mined area was the only source of the elevated constituent concentrations (i.e., constituent concentrations would be expected to attenuate and dilute away from the mined area due to influx of other water sources). However, surface water in Lower Rainy Creek may contain concentrations of inorganic, non-asbestos constituents from mining-related sources (e.g., tailings) in the OU3 Study Area that have possibly washed down Rainy Creek from the area of the Former Libby Vermiculite Mine and remain in sediment.
- Inorganic, non-asbestos constituent concentrations are generally lower in the surface water samples collected from the ponds (relative to the seep and stream locations), and were generally lowest in Tailings Pond surface water samples. This observation implies that inorganic, non-asbestos constituents in surface water are not concentrating in the ponds near the mined area; or, in the case of the Tailings Pond, inorganic, non-asbestos constituent concentrations are being diluted by non-mine-impacted flows from Upper Rainy Creek.

It also should be noted that several of the inorganic, non-asbestos constituents that were found to be elevated relative to reference (including barium, fluoride, and manganese) have the potential to be naturally elevated due the mineralogy of the OU3 Study Area as described in **Section 2.11.1**. As a result, constituent concentrations being elevated within the OU3 Study Area relative to reference locations may not be indicative of mine-related impacts.

5.1.2.4 Detected Organic Constituents in OU3 Study Area Surface Water

The detected organic, non-asbestos constituents in surface water are summarized on **Table 5-2a** and the results are depicted graphically by location in the box-and-whisker plots included in **Appendix H**, **Attachment H-5**. Detected organic, non-asbestos constituents in surface water were limited to:

- Benzene (detected in one of the three samples collected from seep location CCS-14 in October 2007 at a concentration of 0.65 µg/L).
- C5 to C8 aliphatics (detected in one of the three samples collected in October 2007 at seep location CCS-1 at a concentration of 30 µg/L and in seep location CCS-14 at a concentration of 62 µg/L).
- Total extractable hydrocarbons (detected in one of the three samples collected at seep location CCS-8 in June 2008 at a concentration of 571 µg/L, at seep location CCS-14 in October 2007 at a concentration of 320 µg/L, and in FC-Pond on October 2007 at a concentration of 470 µg/L).
- Total purgeable hydrocarbons (detected in one of the three samples collected at seep location CCS-1 in October 2007 at a concentration of 27 µg/L and at seep location CCS-14 in October 2007 at a concentration of 53 µg/L).

With the exception of the one total extractable hydrocarbons detection at FC-Pond, all organic, non-asbestos constituent detections were limited to seep locations, suggesting that the detections could be related to the waste rock piles that overlie the seeps. However, the results indicate that detectable organic, non-asbestos constituents in surface water are limited to benzene and ranges of aliphatics and hydrocarbons, are low level and inconsistently detected (more often below the laboratory detection limit than above), and detections only occurred at three seeps and FC-Pond.

5.1.2.5 Summary of the Nature and Extent of Non-Asbestos Constituents in Surface Water

The data regarding non-asbestos constituents in surface water are summarized below.

- No non-asbestos constituents were detected in OU3 Study Area or reference surface water samples at concentrations that exceed their respective DEQ-7 human health standards or their respective DEQ-7 acute surface water standards for aquatic life.
- Potential mine-related exceedances of DEQ-7 chronic surface water standards for aquatic life are limited to iron and lead, are inconsistent (more often below the DEQ-7 standard than above), and are not widespread in the OU3 Study Area (exceedances occurred only at the FC-Pond location).
- Concentrations of barium, fluoride, manganese and other general water quality parameters were elevated in the OU3 Study Area samples compared to the reference locations. With the exception of fluoride (which was highest in Lower Rainy Creek), the highest concentrations of these constituents generally were detected in the samples collected from the seeps that discharge from the base of the waste rock piles in the Carney Creek drainage. This suggests that higher inorganic, non-asbestos constituents may be due to water interaction with the waste rock piles (which overlie the seeps). However, constituent concentrations that are elevated in the OU3 Study Area relative to reference locations may not be indicative of mine-related impacts due the mineralogy of the OU3 Study Area.
- Qualitative comparative review of the surface water and sediment box-and-whisker plots contained in **Appendix H** indicate that the elevated barium, fluoride, and manganese concentrations in OU3 Study Area surface water (relative to reference) generally do not correlate with constituent concentrations in the sediment sampled at the same locations. The exception is at seep location CCS-16 where there is correlation between barium and manganese concentrations in the surface water and sediment.

- Qualitative comparative review of the inorganic, non-asbestos constituents detected at the seeps with the constituents detected in groundwater sampled from Wells D, E and H do not conclusively support the conceptual model that the groundwater monitored by these wells may be hydraulically connected with water discharging at the seep locations (see **Section 2.9**). Some component of the seep flow may be from interflow, which is the lateral movement of water in the unsaturated zone that first returns to the surface or enters a stream prior to becoming groundwater.
- Detectable organic, non-asbestos constituents in surface water were limited to low levels of benzene and ranges of aliphatics and hydrocarbons, were inconsistently detected (more often below the laboratory detection limit than above), and were not widespread in the OU3 Study Area (detections only occurred at three seeps and FC-Pond).
- The nature and extent of non-asbestos constituents in surface water in the OU3 Study Area is considered adequately defined, and additional evaluations of non-asbestos constituents in surface water are not considered necessary at this time.

5.1.3 Non-Asbestos Constituents in Groundwater

As discussed in **Section 4.3**, groundwater samples were collected from five wells (A, C, D, E, and H) as part of Phase II. The sampled well locations are depicted on **Figure 4-2** and the well construction information is summarized on **Table 2-5**. As summarized on **Table 2-5**, Wells A and C were completed in overburden (alluvium and glacial materials) and Wells D, E, and H were completed in bedrock. The groundwater monitored by these wells is classified *Class I* based on an average SC value of 360 micromhos per centimeter (µmhos/cm) measured in the groundwater samples (see **Section 2.7.3**).

Three rounds of sampling were completed at each well, occurring in the summer and fall of 2008, and the spring of 2009. All Phase II groundwater samples were analyzed for metals and metalloids, petroleum hydrocarbons, anions, nitrogen-containing compounds and other general water quality parameters, cyanide, and selected radionuclides. Additional groundwater samples were collected in 2015, but the analytical suite for the 2015 samples was limited to LAA and general water quality parameters. **Table 5-4** lists the non-asbestos analyses that were performed for groundwater samples from each well and the number of times each well was sampled. **Table 5-5** summarizes the analytical results for non-asbestos constituents that were detected in groundwater. A complete summary of the groundwater analytical results (including non-detected constituents) is contained in **Appendix E**.

The nature and extent evaluation of non-asbestos constituents in groundwater included the following steps:

- Comparison to Montana DEQ-7 standards.
- Evaluation of spatial and temporal trends.

5.1.3.1 Comparison with DEQ-7 Human Health Standards for Groundwater

Non-asbestos results from OU3 Study Area groundwater samples were compared with DEQ-7 human health standards (see **Tables 5-5** and **5-6**). Note that the DEQ-7 standards are used herein solely to aid in the determination of the nature and extent of various constituents and do

not constitute an ARAR determination. Note that DEQ-7 aquatic life standards (acute and chronic) are not intended for groundwater.

Only one non-asbestos constituent was found to exceed DEQ-7 human health standards. Gross alpha in the June 2009 sample collected from Well E (see **Table 5-6**), which had a concentration of 15.7 picocuries per liter (pCi/L), slightly exceeded its respective DEQ-7 human health standard (15 pCi/L). The gross alpha concentrations were well below the DEQ-7 standard in the two other samples collected from Well E (i.e., 6.6 pCi/L in July 2008 and 6 pCi/L in September 2008), and were well below the DEQ-7 standard in all groundwater samples collected from the other OU3 Study Area wells.

Comparison of OU3 Study Area groundwater data with DEQ-7 human health standards suggests that OU3 Study Area groundwater has not been impacted by previous mining activities or existing mine wastes with respect to non-asbestos constituents.

5.1.3.2 Detected Inorganic Constituents in OU3 Study Area Groundwater

Inorganic, non-asbestos results from the OU3 Study Area groundwater samples were evaluated to identify the spatial distribution and possible sources of constituents. The detected inorganic, non-asbestos constituents in groundwater are summarized on **Table 5-5** and the results are depicted graphically by location in the box-and-whisker plots included in **Appendix H, Attachment H-4**. As discussed in **Section 2.11.1.1**, many of these constituents are expected to be detected (i.e., are naturally occurring) at potentially elevated concentrations due to the mineralogy in the OU3 Study Area. There are no site-specific reference groundwater data (i.e., data from locations presumed to be un-impacted by previous mining activities or the presence of mine wastes) to compare with the inorganic, non-asbestos groundwater data collected from the OU3 Study Area. As a result, it is not known if any inorganic, non-asbestos constituents may be elevated compared with concentrations at reference locations as a result of previous mining activities or existing mine waste.

Based on a qualitative review of the box-and-whisker plots, there are no clear patterns in the data to suggest significant differences between bedrock and overburden groundwater. As discussed in **Section 2.9**, the lack of variability in the concentrations of the cations and anions at the Former Mine Area is likely due to the local geology.

Additional discussion of possible correlation between inorganic, non-asbestos constituents detected in bedrock groundwater and inorganic, non-asbestos constituents detected at the seep locations is included above in **Section 5.1.2.4**.

5.1.3.3 Detected Organic Constituents in OU3 Study Area Groundwater

The detected organic, non-asbestos constituents in groundwater are summarized on **Table 5-5** and the results are depicted graphically by location in the box-and-whisker plots included in **Appendix H, Attachment H-5**. Detected organic, non-asbestos constituents in groundwater were limited to:

- Toluene (detected in one of three samples collected from Well D at a concentration of 0.86 µg/L and detected in one of three samples collected at Well E, at a concentration of 0.78 µg/L).

- Total extractable hydrocarbons (detected in one of five samples collected from Well A at a concentration of 926 µg/L, in two of four samples collected from Well E, at concentrations of 391 µg/L and 414 µg/L, and in one of three samples collected from Well H, at a concentration of 1,130 µg/L).

All of the wells that had detectable organic, non-asbestos constituents are located hydraulically up- or cross-gradient from the former mill, landfarming operations, and historical landfill described in **Section 2.11.1.2** (i.e., potential sources of VOC/hydrocarbons). However, no indications of significant organic impacts were detected in groundwater samples.

Based on the groundwater and surface water geochemistry evaluation presented in **Section 2.9**, the groundwater monitored by Wells D, E, and H may be hydraulically connected with water discharging at the seep locations. Further, it is noted that total extractable hydrocarbons were detected in samples from both Wells E and H and the seep locations.

These results indicate that detectable organic, non-asbestos constituents in groundwater were inconsistently detected, and only low levels of toluene and total extractable hydrocarbons were detected.

5.1.3.4 Summary of the Nature and Extent of Non-Asbestos Constituents in Groundwater

The data regarding non-asbestos constituents in groundwater are summarized below.

- The only non-asbestos constituent to exceed a DEQ-7 human health standard was gross alpha in the June 2009 sample collected from Well E. However, overall comparison of OU3 Study Area groundwater data with DEQ-7 human health standards suggests that OU3 Study Area groundwater has not been impacted by previous mining activities or existing mine wastes with respect to non-asbestos constituents.
- Detectable inorganic, non-asbestos constituents in groundwater are naturally occurring and are expected to be detected at potentially elevated concentrations in the OU3 Study Area. There are no clear patterns in the data that suggest possible mine-related sources or causes of elevated constituent concentrations in the groundwater in the OU3 Study Area.
- Organic, non-asbestos constituents in groundwater were detected at relatively low levels for toluene and total extractable hydrocarbons, and were inconsistently detected (i.e., toluene and total extractable hydrocarbons were sometimes above and sometimes below the laboratory detection limit at the same location).
- The nature and extent of non-asbestos constituents in groundwater in the OU3 Study Area is considered adequately defined, and additional evaluations of non-asbestos constituents in groundwater are not considered necessary at this time.

5.1.4 Non-Asbestos Constituents in Sediment

Sediment samples were collected from the same locations and at the same time as surface water samples during Phase I and Phase II (see **Figure 4-3b**). The Phase II sediment sampling plan differed from Phase I for the tailings impoundment and each of the ponds (the Mill Pond and the ponds on Carney Creek and Fleetwood Creek) in that each was sampled by collecting a series of grab samples rather than 1-2 composite samples. A total of 17 grab samples were collected at the tailings impoundment and five grab samples were collected from each pond in order to

investigate the degree of spatial variability of parameter levels in sediments. In addition, sediment samples were collected from various locations during the Phase V Part B investigation, which focused on providing sediment data to support an amphibian metamorphic bioassay conducted for the OU3 Study Area. These locations included both ponds within the OU3 Study Area and reference ponds.

Most sediment samples were analyzed for metals/metalloids, petroleum hydrocarbons, anions, total organic carbon, and other sediment-quality parameters. In addition, several selected sediments were analyzed for a broad suite of other chemicals, including VOCs, SVOCs, pesticides, PCBs, PAHs, and cyanide. **Table 5-7** lists the non-asbestos analyses that were performed for sediment samples from each location and the number of times each location was sampled. **Tables 5-8a** and **5-8b** summarize the analytical results for non-asbestos constituents that were detected in sediment within the OU3 Study Area and outside of the OU3 Study Area, respectively. A complete summary of the sediment analytical results (including non-detected constituents) is contained in **Appendix E**.

The nature and extent evaluation of non-asbestos constituents in sediment included the following steps:

- Comparison to reference locations.
- Evaluation of spatial patterns.

5.1.4.1 Comparison of OU3 Study Area Sediment Data with Reference Data

Inorganic, non-asbestos results from OU3 Study Area sediment samples were compared statistically with the inorganic, non-asbestos results from the reference locations to identify constituent concentrations that were elevated within the OU3 Study Area relative to reference. This evaluation was performed as a line-of-evidence to identify inorganic, non-asbestos constituents that may have elevated concentrations in OU3 Study Area sediment. A description of the statistical evaluation is contained in **Appendix H**. Note that this evaluation was limited to inorganic constituents that occur naturally (e.g., metals/metalloids) because organics are likely to have anthropogenic origin both within and outside of the OU3 Study Area. Therefore, comparing organic constituent concentrations detected in the OU3 Study Area with organic constituent concentrations detected at reference locations would not help determine if the presence of organic constituents in the OU3 Study Area samples are mine-related. A discussion of organic, non-asbestos constituents detected in OU3 Study Area sediment samples is presented separately below in **Section 5.1.4.2**.

Inorganic, non-asbestos constituents that were found to have elevated concentrations relative to reference were evaluated using box-and-whisker plots to identify the sediment sampling locations, or groups of locations, where the elevated constituent concentrations were located in the OU3 Study Area. This information was used to identify the spatial distribution of the elevated inorganic, non-asbestos constituent concentrations, if possible. Note that evaluations of temporal trends are limited because most sediment locations have only been sampled two or three times for non-asbestos constituents.

Sediment reference locations (i.e., locations assumed to be not impacted by previous mining activities or existing mine wastes) include the following (see **Figure 4-3b**):

- Banana Lake
- Bobtail Pond 1
- Bobtail Pond 2
- Bobtail Creek (BTT-R1)
- Noisy Creek (NSY-R1)
- Schrieber Lake
- Tepee Pond 1
- Tepee Pond 2
- Upper Rainy Creek (URC-1, URC-1A, and URC-2)

The inorganic, non-asbestos constituents in the OU3 Study Area sediment samples that had elevated concentrations compared to reference are listed on **Table H-3** (located in **Appendix H**). All of these constituents have the potential to naturally occur in elevated concentrations in the OU3 Study Area compared to areas having different mineralogy (see **Section 2.11.1.1**). Box-and-whisker plots of the analytical results for these constituents are depicted for all OU3 Study Area sediment sampling locations in **Appendix H, Attachment H2**. The box-and-whisker plots are useful for visualizing the locations (or groups of locations) where the inorganic, non-asbestos constituents are elevated, and are useful for visualizing the range of detected concentrations at each location. The box-and-whisker plots indicate that inorganic, non-asbestos constituent concentrations generally are higher in the sediment samples collected from the ponds (Tailings Pond, Carney Creek Pond, Mill Pond) and generally are lower in the sediment samples collected from the creeks (Lower Rainy Creek, Carney Creek, Fleetwood Creek) and in the seeps; (note that this is opposite of the inorganic, non-asbestos constituent concentrations in surface water, which were generally lower in the ponds and generally higher in the seeps and streams). Of the pond locations, inorganic, non-asbestos constituent concentrations tend to be highest in sediment locations in the Mill Pond and Tailings Pond. These data suggest that the bulk of potentially mine-impacted sediment are contained in the fine tailings behind the KDID (i.e., within the Tailings Pond) and sediments in the Mill Pond, and to a lesser extent in the sediments that have accumulated in Fleetwood Pond and Carney Creek Pond.

Within the Tailings Pond, inorganic, non-asbestos constituent concentrations generally were lowest at sediment sampling location TP-17, which is located at the north end of the pond and upstream of where sediment entrained in flow from Fleetwood Creek and runoff from the Tailings Pile enters the pond (see **Figure 4-3b**). Within the Mill Pond, inorganic, non-asbestos concentrations generally were highest in the samples collected in the middle of the pond (MP-1 and MP-2), and lowest along the south end of the pond (MP and MP-5; see **Figure 4-3b**). The box-and-whisker plots otherwise indicate a high degree of spatial variability of the inorganic, non-asbestos constituent concentrations in the sediments within each pond.

5.1.4.2 Detected Organic Constituents in OU3 Study Area Sediment

The detected organic, non-asbestos constituents in OU3 Study Area sediment samples are summarized on **Table 5-8a** and the results are depicted graphically by location in the box-and-whisker plots included in **Appendix H**, **Attachment H5**. The SVOC/PAH constituents detected in sediments were located in the Tailings Pond and Lower Rainy Creek (LRC-2 and/or TP-TOE2) and were inconsistent (more often below the laboratory detection limit than above). These results indicate that the presence and distribution of SVOC/PAH constituents in sediments in the OU3 Study Area is not significant or widespread.

Volatile organic compound (VOC)/hydrocarbon detections in OU3 Study Area sediments were limited to toluene, naphthalene, and extractable aliphatics or hydrocarbons. The extractable aliphatics/hydrocarbon detections generally have similar distribution and trends as the inorganic, non-asbestos constituents in sediment described above (i.e., generally are higher in the sediment samples collected from the ponds and generally highest in sediment locations in the Mill Pond and Tailings Pond). Naphthalene detections were limited to two samples collected from the tailing pond and one sample collected from the Mill Pond. Toluene was detected in one sample collected at seep location CCS-1. These results also suggest that the presence and distribution of VOCs/hydrocarbons in sediments in the OU3 Study Area is not significant or widespread.

5.1.4.3 Summary of the Nature and Extent of Non-Asbestos Constituents in Sediment

The data regarding non-asbestos constituents in sediment are summarized below.

- Several inorganic, non-asbestos constituents were found to have elevated concentrations in the OU3 Study Area sediment samples relative to the reference sampling locations. However, constituent concentrations being elevated in the OU3 Study Area relative to reference locations may not be indicative of mine-related impacts due to the mineralogy of the OU3 Study Area.
- Inorganic, non-asbestos constituent concentrations generally were higher in the sediment samples collected from the ponds (e.g., Tailings Pond, Carney Creek Pond, Mill Pond) and generally were lower in the sediment samples collected from the creeks (Lower Rainy Creek, Carney Creek, Fleetwood Creek) and in the seeps. This is opposite of the inorganic, non-asbestos constituent concentrations in surface water, which were generally lower in the ponds and generally higher in the seeps and streams.
- Inorganic, non-asbestos constituent concentrations tend to be highest in sediment locations in the Mill Pond and Tailings Pond. These data suggest that the bulk of potentially mine-impacted sediment are contained in the fine tailings behind the KDID (i.e., within the Tailings Pond) and sediments in the Mill Pond, and to a lesser extent in the sediments that have accumulated in Fleetwood Pond and Carney Creek Pond.
- Organic, non-asbestos constituent data suggest that the presence and distribution of VOCs/hydrocarbons in sediments in the OU3 Study Area is not significant or widespread.
- The nature and extent of non-asbestos constituents in sediment in the OU3 Study Area is considered adequately defined, and additional evaluations of non-asbestos constituents in sediment are not considered necessary at this time.

5.1.5 Non-Asbestos Constituents in Soil/Mine Waste

Figure 4-4b depicts the locations where samples of soil/mine waste materials were collected. Samples were collected from each of the principal mine waste materials that have been identified in the OU3 Study Area (mine waste rock, fine tailings, and coarse tailings), and from soils in the former mill area and roadway materials used for construction of unpaved sections of Rainy Creek Road. Forest soil samples (from the distal ends of the asbestos-sampling transects described in **Section 4.6.1**) were used to provide data from reference locations (i.e., locations presumed not to be impacted by previous mining activities or the presence of mine wastes).

All soil/mine waste samples were analyzed for metals/metalloids, anions, and other soil quality parameters. Mine waste rock, tailings, soil from the former mill area, and roadway materials were also analyzed for petroleum hydrocarbons and the three roadway materials samples were analyzed for PCBs and PAHs. Samples collected from the fine tailings were analyzed for a broad suite of other chemicals, including VOCs, SVOCs, pesticides, PCBs, and PAHs. The reference forest soil samples were analyzed for metals/metalloids only. **Table 5-9** lists the non-asbestos analyses that were performed for soil/mine waste samples from each location and the number of times each location was sampled. **Table 5-10** summarizes the analytical results for non-asbestos constituents that were detected in the soil/mine waste samples. A complete summary of the soil/mine waste analytical results (including non-detected constituents) is contained in **Appendix E**.

The nature and extent evaluation of non-asbestos constituents in soil/mine waste included the following steps:

- Comparison to Montana Background Soils.
- Comparison to reference locations.
- Evaluation of spatial patterns.

5.1.5.1 Comparison of Inorganic Constituents with Montana Background Threshold Concentrations

Non-asbestos results from OU3 Study Area soil/mine waste and reference forest soil samples were compared directly to background threshold concentrations of inorganic constituents in Montana surface soils (Hydrometrics, Inc., 2013). These comparisons with Montana background concentrations were made only to provide context to the constituent concentrations in the mine waste and forest soil.

The constituents in the OU3 Study Area soil/mine waste samples and reference forest soil sample locations that exceeded Montana background concentrations are listed on **Tables 5-10** and **5-11**. Several inorganic constituents exceeded the Montana background threshold concentrations in both OU3 Study Area and reference sample locations, including aluminum, chromium, cobalt, iron, nickel, and vanadium. Barium, lead, and thallium exceeded Montana background threshold concentrations in the OU3 Study Area samples, but not in the reference samples; and cadmium and manganese exceeded the Montana background threshold concentration in the reference samples but not in the OU3 Study Area samples. All of the inorganic, non-asbestos constituents that exceeded Montana background threshold concentrations in the OU3 Study Area samples have the potential to be naturally present in elevated concentrations based on the mineralogy of the OU3 Study Area (i.e., elevated concentrations compared with locations that have different mineralogy; see **Section 2.11.1.1**). Therefore, these exceedances of the Montana background threshold concentrations in the OU3 Study Area soil/mine waste samples are not unexpected, and are not necessarily indicative of mine-related impacts.

5.1.5.2 Comparison of OU3 Study Area Soil/Mine Waste Data with Forest Soil Reference Data

Forest soil samples (from the distal ends of the asbestos-sampling transects described in **Section 4.6.1** and shown on **Figure 4-4b**) were analyzed for non-asbestos constituents (metals/metalloids only) to provide data from reference locations (i.e., locations assumed to not be impacted by previous mining activities or the presence of mine wastes). Inorganic, non-asbestos results from OU3 Study Area soil/mine waste samples were compared statistically with

the inorganic, non-asbestos results from the reference sampling locations to identify constituent concentrations that are elevated relative to reference. A description of the statistical evaluation is contained in **Appendix H**. This evaluation was performed as a line-of-evidence to identify inorganic, non-asbestos constituent concentrations that may be elevated in the OU3 Study Area. Note that this evaluation was limited to inorganic constituents that occur naturally (i.e., metals/metalloids) because organics are likely to have anthropogenic origin both within and outside of the OU3 Study Area. Therefore, comparing organic constituent concentrations detected in the OU3 Study Area with organic constituent concentrations detected at reference locations would not help determine if the presence of organic constituents in the OU3 Study Area samples are mine-related. A discussion of organic, non-asbestos constituents detected in OU3 Study Area soil/mine waste samples is presented separately below in **Section 5.1.5.3**.

Inorganic, non-asbestos constituents in the soil/mine waste samples that were found to have elevated concentrations relative to reference forest soil were evaluated to identify the soil/mine waste sampling locations, or groups of locations, where the elevated constituent concentrations were located in the OU3 Study Area. This information was used to identify the spatial distribution of the elevated non-asbestos constituent concentrations, if possible. Temporal trends cannot be evaluated because locations only were sampled once or twice for non-asbestos constituents; however, temporal trends are not anticipated for inorganic, non-asbestos constituents in soil/mine waste.

The inorganic, non-asbestos constituents in the OU3 Study Area soil/mine waste samples that had elevated concentrations compared to reference are listed on **Table H-4** (located in **Appendix H**), and include aluminum, barium, chromium, cobalt, copper, iron, nickel, and vanadium. The analytical results for these constituents are plotted for all OU3 Study Area soil/mine waste sampling locations in **Appendix H**, **Attachment H-3**. The data plots show that the highest concentrations of these constituents were detected in the two multi-point composite samples collected from the tailings impoundment and some outcrop samples. However, other outcrop samples had low concentrations of these constituents relative to other OU3 Study Area locations. It should be noted that elevated concentrations of naturally occurring metals/metalloids are expected in outcrop samples. There are no other obvious trends that can be seen on the soil/mine waste data plots with regard to spatial distribution or potential sources of inorganic, non-asbestos constituents in the soil/mine waste. As discussed above in **Section 5.1.5.1** and **2.11.1.1**, these results are not unexpected because of the mineralogy of the OU3 Study Area, and are not necessarily indicative of mine-related impacts.

5.1.5.3 Detected Organic Constituents in OU3 Study Area Soil/Mine Waste

The detected organic, non-asbestos constituents in the soil/mine waste samples are summarized on **Table 5-10** and the results are depicted graphically by sampled location in the box-and-whisker plots included in **Appendix H**, **Attachment H-5**. Of the six locations that were analyzed for SVOCs/PAHs, the detectable SVOC/PAH constituents were limited to the two samples collected from the tailings impoundment (MS-4 and MS-5). Detected VOCs were limited to a single detection of toluene in one sample collected from the central waste rock pile (MS-14; 0.066 mg/kg), and detections of methyl acetate in each of the two samples collected from the tailings impoundment (MS-4; 0.56 mg/kg and MS-5; 1.7 mg/kg). These results indicate that the presence and distribution of SVOCs/PAHs and VOCs in soil/mine waste in the OU3 Study Area is not significant or widespread.

Total extractable hydrocarbons were detected in most soil/mine waste samples, with relatively higher concentrations detected in the Rainy Creek road material samples, in fine tailings samples,

and in one sample collected from the east waste rock pile (MS-20). The exception is that concentrations of total extractable hydrocarbons were below the practical quantification limit (PQL) in all four samples collected from the coarse tailings. Concentrations of total purgeable hydrocarbons were below the PQL in most samples analyzed with the exceptions of one sample from the west waste rock pile (MS-28) and two samples from the central waste rock pile (MS-14 and MS-18). Of the six locations that were analyzed for C9 to C18 aliphatics, detections were limited to the two samples collected from the tailings impoundment (MS-4 and MS-5). Of the six locations that were analyzed for C19 to C36 aliphatics, detections included all three road material samples collected from the Rainy Creek Road area (MS-1, MS-2, and MS-3), both samples collected from the fine tailings (MS-4 and MS-5), and one sample in the east waste rock pile (MS-20). For C11 to C22 aromatics, detections included all three road material samples collected from the Rainy Creek Road area (MS-1, MS-2, and MS-3), one sample collected from the fine tailings (MS-5), and one sample in the east waste rock pile (MS-20). Other ranges of hydrocarbons in the soil/mine waste samples were generally below the PQL (e.g., C5 to C8 aliphatics and C9 to C10 aromatics), with the exception of one sample collected in the central waste rock pile (MS-14). These detections of various hydrocarbons do not exhibit clear spatial patterns that indicate specific areas that are impacted or potential sources of hydrocarbon contamination.

5.1.5.4 Summary of the Nature and Extent of Non-Asbestos Constituents in Soil/Mine Waste

The data regarding non-asbestos constituents in soil/mine waste are summarized below.

- Several inorganic, non-asbestos constituents exceeded the Montana background threshold concentrations in both OU3 Study Area and reference sample locations; and several inorganic, non-asbestos constituents were found to have elevated concentrations relative to the reference sampling locations. These results are not unexpected because of the mineralogy of the OU3 Study Area, and are not necessarily indicative of mine-related impacts.
- The presence and distribution of SVOCs/PAHs and VOCs in soil/mine waste in the OU3 Study Area is not significant or widespread. Ranges of hydrocarbons were detected in the soil/mine waste samples across the OU3 Study Area. These detections of various hydrocarbons do not exhibit clear spatial patterns that indicate specific areas that are impacted or potential sources of hydrocarbon contamination.
- The nature and extent of non-asbestos constituents in soil/mine waste in the OU3 Study Area is considered adequately defined, and additional evaluations of non-asbestos constituents in soil/mine waste are not considered necessary at this time.

5.2 NATURE AND EXTENT OF LAA

The nature and extent of LAA in various media are presented in this section. Because LAA is naturally occurring within the OU3 Study Area due to the presence of the large mineral deposit and natural geologic and glacial conditions, it is likely that the LAA detections in all media are related to both natural and anthropogenic movement of naturally occurring sources. Data relevant to background concentrations in the mine area are discussed below. However, to date, no background or reference LAA levels have been established that are directly applicable to the OU3 Study Area.

The EPA evaluated data gathered as part of the nature and extent evaluation for the OU3 Study Area in its risk assessments that are summarized in **Section 7.0**. A complete data summary for all RI LAA data is included in **Appendix E**.

5.2.1 LAA Data Considerations

5.2.1.1 LAA Data Adequacy Evaluation

There were a variety of field QC samples, preparation laboratory QC samples, and analytical laboratory QC analyses included as part of the sampling investigations performed in the OU3 Study Area. A detailed review and discussion of the results for QC samples and analyses is provided in the annual QA/QC summary reports for the OU3 Study Area prepared by EPA's QATS contractor. These reports are provided in **Appendix G**. In summary, the quality of the LAA data was deemed sufficient for the intended use.

LAA data collected as part of the OU3 Study Area RI for LAA in surface water, sediment, groundwater, and soil/mine waste were considered adequate to support the risk assessments. Risk assessments performed were documented in the reports titled: *Final Site-wide Human Health Risk Assessment* (for LAA) (EPA, 2015a) and the *Final Site-wide Baseline Ecological Risk Assessment* (for LAA) (EPA, 2014a), which are discussed in **Section 7.0**.

5.2.1.2 LAA Background and Naturally Occurring Materials Data

As discussed in **Section 2.6.1**, EPA conducted an investigation at the Libby Site to characterize LAA in soil from areas that were thought to be representative of background conditions. The investigation was presented in the document titled: *Final Background Soil Summary Report Libby Asbestos Superfund Site, Montana* (CDM Smith, 2014b). The primary conclusion of the report was that there is a non-zero level of LAA in soils within the Kootenai Valley that is not attributable to vermiculite mining and processing activities at the Libby Site. The average total LAA concentration in background soil was estimated to be approximately 0.014% by mass. However, while these estimates may be representative of background conditions within the Kootenai Valley, they likely are not representative of background conditions within the OU3 Study Area. This is because of the unique natural geologic character of Vermiculite Mountain (i.e., a large, high-quality vermiculite ore body containing high percentages of fibrous and asbestiform amphiboles), which was the reason the site was mined. As a result, it can be inferred that background LAA concentrations within the OU3 Study Area (i.e., proximal to Vermiculite Mountain) would be higher than the more distal surrounding areas where the EPA conducted the background study. However, the true nature of background LAA concentrations in the OU3 Study Area has not been established.

The report titled: *Test Pit LAA Results and Creek Reconnaissance Report, OU3 Study Area* (MWH, 2016a; see also **Section 4.5.5**) included identification and LAA-concentration testing of naturally occurring, non-mine-impacted geologic materials located near the KDID. Fine fraction (PLM-VE) LAA concentrations in these naturally occurring materials ranged from ND (Bin A) to 1% (Bin C) in the glacial materials, and were as high as 2% in the pyroxenite bedrock samples (although outcrop samples collected during other sampling events have measured LAA at levels up to 8%). Naturally occurring LAA within the glacial deposits and bedrock outcrops would be expected to contribute to LAA in surface water along Rainy Creek due to natural erosional processes. Although these results support the conceptual model that background LAA concentrations within the OU3 Study Area are higher than the more distal surrounding areas,

additional sampling and analysis of representative materials would be required in order to establish background levels for the various media in the OU3 Study Area.

Because there are not LAA-specific benchmarks or reliable background levels for the OU3 Study Area, the detected LAA concentrations in the various media are largely presented below in terms of detected concentrations and concentration ranges. The exceptions to this are LAA concentrations in surface water and groundwater, which are compared with the National Primary Drinking Water Regulation (NPDWR) Maximum Contaminant Level (MCL) for asbestos of 7 million fibers per liter of water (MFL). The MCL is based on fibers longer than 10 µm in length (>10 µm).

5.2.2 LAA Concentrations in Soil, Mine Waste, and Bedrock

As described in **Section 4.5,** the forest soil, soil and mine waste, and bedrock samples collected during various sampling phases/events were analyzed for a broad suite of analytes, including LAA. The following is a discussion of the nature and extent of LAA in each of these media. A comprehensive analytical data summary is provided in **Appendix E**.

Overview. **Tables 5-12a** through **5-15b** present the summary statistics (minimum, maximum, mean, number of detections, etc.) for LAA results and analysis type (fine fraction; PLM-VE and coarse fraction; PLM-Grav) for forest soil, former mine area soil, bedrock, and mine waste samples for both sample area/material type and station. All samples were analyzed for PLM-VE and only select samples where a coarse fraction was present were analyzed for PLM-Grav. For consistency on how soil samples were evaluated and interpreted at the other OUs within the Libby Site, the fine fraction and coarse fraction samples were not combined as per the procedures described in *Technical Memo 8* (EPA, 2008f). Rather, *Technical Memo 8* was only referenced to obtain the semi-quantitative values (surrogate values) for the various qualitative soil results in order to derive mean values for specific groupings of soil and soil like samples. For example, for results of Bin B2 (<1%) the surrogate value of 0.6% was used as provided in *Technical Memo 8.* Once each qualitative soil result was replaced with a surrogate value, means could then be calculated. The coarse fraction (PLM-Grav) results are presented in the data tables in order to provide all of the analytical results from the RI but are not discussed herein. **Figures 5-1a** and **5-1b** present the spatial pattern of fine fraction LAA (PLM-VE) of samples collected in the vicinity of the Former Mine Area, which are discussed herein. In general, the highest percentages of PLM-VE LAA reported in samples were from road soil (25%, sample TS-C-11, collected on a mine bench), bedrock (8%, outcrop sample MS-25), waste rock (5%, sample MS-15), and coarse tailings (4%, sample GT-11). The extent of LAA (PLM-VE) levels in soil, mine waste, and bedrock samples ≥0.2% by mass (the lowest quantifiable level using the EPA-approved method) is shown on **Figures 5-1a** and **5-1b**. As shown on **Figures 5-1a** and **5-1b**, the area with LAA (PLM-VE) in soil, mine waste, or bedrock ≥0.2% encompasses approximately 1,544 acres, although LAA was detected at levels below 0.2% beyond this area.

Forest Soil. Forest soils were collected in the forested areas shown on **Figure 4-5a** and the analytical data are summarized on **Tables 5-12a** (by distance from former mine area center) and **5-12b** (by station). Note that soils collected during post-burn events are not summarized in these tables because they do not represent native forest soil conditions, rather post-burn soil summary results are presented in **Table 5-24**. The extent of forest soil LAA detections in the vicinity of the Former Mine Area is shown on **Figures 5-1a** and **5-1b** for the fine fraction (PLM-VE) only. As shown on **Figures 5-1a** and **5-1b** and on **Tables 5-12a, Panel A** and **5-12b, Panel A**, of the 89 samples collected and analyzed for LAA (PLM-VE), the only forest soil samples with detections of LAA (trace or higher) were collected within approximately two miles from the center of the Former

Mine Area (Near). One sample (SL135-01, located between the former mill site and the KDID) had a LAA result of Bin C (6%), two samples (SL45-01, located 0.5 mile northwest of the mine center, and SP15-Pre-S, located 1 mile to the north-northwest of the mine center) had results of Bin B2 (≥0.2% and <1%), 12 samples had results of Bin B1 (above ND, but less than 0.2%), and 74 of the sample locations were Bin A (ND). None of the forest soil samples collected more than two miles beyond the mine center had any LAA detections by PLM-VE.

Former Mine Area Soil. The locations and LAA levels (PLM-VE) for Former Mine Area soil samples are shown on **Figure 5-1a** and summarized on **Tables 5-13a** (by material) and **5-13b** (by station). As shown on **Tables 5-13a, Panel A** and **5-13b, Panel A** the range of LAA (PLM-VE) in Former Mine Area soil was Bin A (ND) to Bin C (up to 25%). Former Mine Area soils were grouped into material categories for evaluation. The ranges and mean values of LAA (PLM-VE) for each of the soil material categories are presented below.

- Road Material: the range of LAA was ND to 25% (sample TS-C-11, collected on a mine bench), with a mean value of 2%.
- Cover/Fill Material: the range of LAA was ND to 3% (samples GT-14, GT-15, and GT-26), with a mean value of 1%.
- Alluvium/Other Material: the range of LAA was <0.2% to 2% (samples VW-1-10, VW-1-14, and VW-1-15), with a mean value of 0.4%.
- Glacial Material: the range of LAA was ND to 1% (sample GT-16), with a mean value of 0.2%.

Bedrock. LAA occurs in cross-cutting veins and dikes that occur throughout the pyroxenite bedrock. These veins and dikes generally range from a few millimeters to several meters in thickness, and the LAA concentration in these zones is estimated to range between 50-75% (Meeker *et al.,* 2003). The locations and LAA levels (PLM-VE) for Former Mine Area bedrock samples are shown on **Figure 5-1a** and were taken from bedrock outcroppings or where bedrock was encountered in a test pit. As shown on **Tables 5-14a, Panel A** and **5-14b, Panel A**, the range of LAA (PLM-VE) in bedrock samples was ND (sample GT-19) to 8% (sample MS-25), with a mean value of 1%. LAA-bearing veins were not targeted by the bedrock sampling program, which may explain the variability in LAA concentrations in these samples

Mine Waste. The areal extent and approximate volumes of mine waste are shown on **Figure 5-2.** Approximately 40.7 million cubic yards (MCY) of waste rock, 3.2 MCY of fine tailings, and 14.7 MCY of coarse tailings are present at the site. Approximately 1.2 MCY of coarse tailings were used to construct the KDID. As shown on **Tables 5-15a, Panel A** and **5-15b, Panel A**, the range of LAA (PLM-VE) in coarse tailings was from Bin B2 (≥0.2% to <1%) to Bin C (4%, sample G-11), with a mean value of 1%. The range of LAA (PLM-VE) in fine tailings was within Bin B2 (≥0.2% to <1%) with a mean value of 0.6%. The range of LAA (PLM-VE) in waste rock was from Bin B2 (≥0.2% to <1%) to Bin C (up to 5%, sample MS-15), with mean values ranging from 0.6% (Bin B2, central and east piles) to 2% (Bin C, west pile).

5.2.2.1 Summary of the Nature and Extent of LAA in Soils and Mine Waste

The data regarding LAA in soils and mine waste are summarized below.

- In general, the highest percentages of LAA (PLM-VE) reported in samples were from road soil (25%, sample TS-C-11, collected on a mine bench), bedrock (8%,

outcrop sample MS-25), waste rock (5%, sample MS-15), and coarse tailings (4%, sample GT-11).

- The extent of LAA (PLM-VE) levels in soil, mine waste, and bedrock samples ≥0.2% by mass extends approximately 1,544 acres within the boundaries of the Former Mine Area and along Rainy Creek, although LAA was detected at levels below 0.2% beyond this area.
- The only forest soil samples with detections of LAA (PLM-VE) (trace or higher) were collected within approximately two miles from the center of the Former Mine Area (Near).
- Approximately 40.7 million cubic yards (MCY) of waste rock, 3.2 MCY of fine tailings, and 14.7 MCY of coarse tailings are present within the boundaries of the Former Mine Area.

5.2.3 LAA Concentrations in Groundwater

As described in **Section 4.3**, select groundwater wells and piezometers were sampled in 2008 (July and September), 2009 (June), and 2015 (April and May) for analysis for a broad suite of analytes, including LAA. Groundwater wells and piezometers were screened in overburden, alluvial, or glacial material (collectively referred to as "shallow" wells/piezometers) and in bedrock. Groundwater well and piezometer locations are shown on **Figure 4-2** and **Figure 5-3**. Results, presented below, are compared with the NPDWR MCL for asbestos in water of 7 MFL (based on fibers >10 µm). The groundwater analytical data are provided in **Appendix E**. A summary of LAA concentrations in groundwater samples is provided in **Tables 5-16a** (by screened area) and **5-16b** (by station). LAA was detected in some of the equipment rinsate blank samples that were collected during the 2015 sampling event. As a consequence, the EPA third party validator, CB&I, blank-adjusted the groundwater results to account for the possibility of cross-contamination between samples collected in the field using the contaminated equipment. The blank-adjustment method is documented in a record of modification form attached to a memorandum that discusses these samples specifically (see **Appendix I**).

As shown in **Table 5-16a**, 20 samples were collected from eight shallow well/piezometer locations and 14 samples were collected from bedrock wells. Total[6] LAA was detected in groundwater samples from all of the wells/piezometers except for piezometers BH-05A-1 and BH-07A-1 and Well D. Detected total LAA levels ranged from 0.90 MFL (Well E) to 139 MFL (BH-03A-1). However, only two samples, both of which were collected from shallow wells/piezometers, contained concentrations of LAA >10 µm greater than the MCL (see **Table 5-16b**). The samples from piezometer BH-01A-2 (7.7 MFL, collected on May 21, 2015) and piezometer BH-03A-1 (12 MFL, collected on April 19, 2015) contained LAA levels above the MCL. Both piezometers were installed as part of the KDID geotechnical investigation that occurred in 2014; with BH-01A-2 installed within the fine tailings impoundment and BH-03A-1 installed within the up-gradient, central portion of the KDID embankment (see **Figure 5-3**). Elevated LAA levels in these two samples are thought to be related to suspended sediment in the water at the time of sampling, given that the other samples collected in 2015 from both piezometers (BH-01A-2, 1.4 MFL on April 19, 2015 and BH-03A-1, 1.5 MFL on May 19, 2015) had significantly lower LAA levels. In addition, sampling pump issues were noted during the April 2015 sampling in BH-03A-1. The pump had to be removed and replaced in the well prior collection of the sample. It is also noted that none of the other shallow wells/piezometers located down-gradient from piezometers BH-

[6] "Total" is used to define all the countable LAA structures recorded during the TEM analysis (i.e., all structures with length ≥0.5 µm).

01A-2 and BH-03A-1 contained LAA levels above the MCL. This indicates that significant down-gradient migration of LAA is not occurring within shallow groundwater.

As shown, in **Table 5-16b**, none of the bedrock groundwater samples contained concentrations of LAA above the MCL. This illustrates that although a downward vertical flow gradient (from overburden materials towards bedrock) is indicated in the vicinity of the KDID (see **Section 2.7.2**), no significant LAA-impacts in bedrock groundwater are indicated by the analytical data. **Figure 5-3** displays the spatial pattern of the maximum detected concentrations of LAA >10 µm in length in groundwater.

It has been demonstrated (see **Section 5.2.4**) that LAA levels in surface water are directly related to flow velocity. Given the low seepage velocity and natural filtration that typically occurs in porous aquifers, it is expected that very little transport of LAA would occur within groundwater. The general lack of significant LAA levels detected in groundwater samples collected over time supports this assumption.

5.2.3.1 Summary of the Nature and Extent of LAA in Groundwater

The data regarding LAA in the groundwater are summarized below.

- Only two of the 20 samples collected from shallow wells/piezometers contained concentrations of LAA greater than the MCL. Both are attributed to sediment (due to insufficient development and/or pump issues) in the piezometers.
- No impacts above the MCL in bedrock groundwater were observed.
- Given the low seepage velocity and natural filtration that typically occurs in porous aquifers, it is expected that very little transport of LAA would occur within groundwater.

5.2.4 LAA Concentrations in Surface Water, Sediment, and Pore Water

As described in **Section 4.2** and **Section 4.4**, the surface water and sediment samples collected during the various sampling phases/events were analyzed for a broad suite of analytes, including LAA and non-asbestos constituents. The following is a discussion of the nature and extent of LAA constituents in surface water, sediment, and pore water. For the purposes of evaluating nature and extent of LAA along the Kootenai River, surface water sample results collected as part of the OU4 RI also are included (CDM Smith, 2014a). The comprehensive surface water, sediment, and pore water analytical data summary for LAA is provided in **Appendix E**.

A summary of the LAA concentrations in surface water is provided in **Table 5-17a** (by surface water area) and **Table 5-17b** (by station). All surface water LAA sampling locations are presented on **Figure 4-1a**. Note that the 10 surface water sample results collected using a syringe for free fiber analysis during Phase IV, Part B are not included in the summary of results below because the collection method varied from the standard sampling methods for all other surface water samples. The results for the free fiber analysis are located in **Appendix E**.

Tables 5-18a and **5-18b** present the summary statistics (detections by Bin, number of detections, etc.) for LAA results and analysis type (**Panel A**: PLM-VE and **Panel B:** PLM-Grav, if a coarse fraction was present) for sediment samples by surface water area and by station, respectively. All sediment LAA sampling locations are presented on **Figure 4-3a**. Sediment data using LAA (PLM-VE) are used for discussion purposes herein and are presented on **Figures 5-4b** and **5-4c**.

The watersheds of Fleetwood Creek, Carney Creek, and Rainy Creek, as well as the Rainy Creek discharge into the Kootenai River are shown on **Figure 2-5a**. An evaluation of each stream reach in the OU3 Study Area and the Kootenai River is presented below to describe the concentration, distribution, and potential sources of LAA in the surface water and sediment. As shown on **Tables 5-17a** and **5-17b**, total LAA was detected in all of the water bodies within the OU3 Study Area at maximum levels that ranged from 1.3 MFL (Kootenai River) to 1,200 MFL (Tailings Pond area). The following discussion presents surface water data for LAA fibers >10 µm, which is the standard for comparison with the MCL of 7 MFL.

As discussed in **Sections 4.2.6** and **4.2.8**, pore water samples were collected during the Phase V Part B investigations to support the ecological risk assessment. LAA concentrations in pore water samples are provided in **Appendix E**. All pore water LAA sampling locations are co-located with sediment sampling locations as presented on **Figure 4-3a** and the pore water results are discussed in **Section 5.2.4.5**.

5.2.4.1 Fleetwood Creek

This evaluation of Fleetwood Creek surface water and sediment includes sample data from Fleetwood Creek (sample locations FC-1 and FC-2) and Fleetwood Pond (sample location FC-Pond). Surface water data for maximum LAA concentrations (>10 µm) per sample location are presented on **Figure 5-4a**.

Fleetwood Creek Surface Water. The three Fleetwood Creek sampling locations, as well as time series graphs of LAA concentrations and flow rates, are shown in **Figure 5-5a**. A general correlation between flow rate and LAA concentrations can be seen at the sample locations FC-1 and FC-2. Flow data are not applicable at FC-Pond because flow is expected to be negligible in the pond. As shown on **Table 5-17a**, of the 46 surface water samples collected within Fleetwood Creek (including the FC-Pond) from three stations, the concentrations of LAA >10 µm range from 0 MFL to 289 MFL with a mean of 8.7 MFL. The sample result of 289 MFL, collected on September 12, 2008, is suspect as it is an order of magnitude higher than all other samples collected at that sample location (see graph for FC-Pond in **Figure 5-5a**). The DSR (CDM Smith, 2016) notes that the higher result in this sample could be attributable to higher amounts of sediment in this sample as a consequence of sample collection methods using a peristaltic pump and tubing. Therefore, if this sample is discounted, the maximum concentration of LAA >10 µm is 28 MFL (also at FC-Pond). All other LAA concentrations at FC-Pond are less than or equal to 7 MFL.

Figure 5-5b shows the summary statistics and the elevation of each sampling location in Fleetwood Creek (also presented in **Table 5-17b**). The maximum concentrations of LAA >10 µm collected in surface water from upstream to downstream sample locations in Fleetwood Creek are as follows:

- FC-1: 0.92 MFL
- FC-Pond: 289 MFL (as discussed above, this result is likely due to a sample collection anomaly and is not considered representative of surface water concentrations in FC-Pond)
- FC-2: 3.1 MFL

Based on the data presented in **Table 5-17b** and shown in **Figure 5-5b,** MCL exceedances for LAA occur only at sampling station FC-Pond. LAA MCL exceedances are recorded in six of 23 samples (26%) in FC-Pond, which is adjacent to and downslope of the coarse tailings. LAA entrained in runoff from the coarse tailings likely is the source of the higher LAA concentrations detected at FC-Pond and FC-2 locations (relative to the LAA concentrations in the upstream FC-1 location, which does not receive runoff from the coarse tailings). The higher LAA concentrations in the FC-Pond surface water relative to the upstream and downstream sampling locations may indicate that LAA accumulates in the pond, possibly as a result of the negligible flow rates in the pond relative to the stream, which allows the suspended LAA to settle in the pond. The concept that LAA concentrates in FC-Pond relative to the stream is supported by the sediment data discussed below (i.e., LAA concentrations also are higher in the FC-Pond sediment samples relative to the stream). It also is likely that the higher LAA concentrations in the coarse tailings adjacent to the pond relative to the LAA concentrations in the coarse tailings closer to the FC-2 sampling location directly influence the LAA concentrations in the surface water in FC-Pond and FC-2 (see **Figures 5-1a** and **5-4a**).

The slope between the sampling stations in Fleetwood Creek is generally uniform with a slight increase in slope between FC-Pond and FC-2. This increase in slope may impact the higher concentrations of LAA at FC-2 due to increased energy and erosion that would be associated with higher flow velocities.

Fleetwood Creek Sediment. As shown on **Tables 5-18a, Panel A** (by surface water area) and **5-18b, Panel A** (by station), a total of 22 sediment samples were collected along Fleetwood Creek and analyzed for fine-fraction (PLM-VE) LAA from nine sample locations. The maximum LAA concentrations (PLM-VE) from upstream to downstream sediment sample locations within Fleetwood Creek are as follows:

- FC-1: Bin B1 (>ND to <0.2%)
- FC-Pond: Bin C (up to 4%)
- FC-2: Bin B1 (>ND to <0.2%)

All LAA sample results (PLM-VE) for FC-1 and FC-2 are either Bin A (ND) or Bin B1 (trace; detected LAA <0.2%). Samples in the Fleetwood Creek Pond ranged from Bin B1 (>ND to <0.2%) to Bin C (≥1%). A total of 15 sediment samples were collected within FC-Pond and two samples were Bin B1 (trace; detected LAA <0.2%), nine samples were Bin B2 (≥0.2% to <1%), and four samples were Bin C (≥1%). All four Bin C sample results were collected from either FC-Pond (three samples) or FC-POND-1 (one sample), which are in close proximity to each other near the southern bank of the pond nearest the stream outlet (see **Figure 5-4b**). The FC-Pond location has the highest mean concentration at 2% by percent mass, whereas both FC-1 and FC-2 have mean concentrations of 0.1% by percent mass. Too few samples were collected at all other FC-Pond sample locations (i.e., FC-POND 1, FC-POND 2, etc.) to accurately calculate a mean by percent mass value.

As with the surface water data discussed above, the source of the LAA detected in the sediment likely is the coarse tailings adjacent to the Fleetwood Creek. The higher LAA concentrations in the Fleetwood Creek Pond relative to the stream sampling locations likely are a result of the difference in flow-rate between the pond and the creek (which allows LAA to settle out in sediments in the pond), or due to the higher LAA concentrations in the coarse tailings near the pond.

5.2.4.2 Summary of the Nature and Extent of LAA in Fleetwood Creek Surface Water and Sediment

The data regarding LAA in Fleetwood Creek surface water and sediment are summarized below.

- MCL exceedances for LAA in surface water only occur at sampling station FC-Pond, which is adjacent to and downslope of the coarse tailings. The highest surface water concentration in FC-Pond of is 28 MFL. (The sampling result of 289 MFL is suspected to be anomalous due to sampling bias.)
- LAA entrained in runoff from the coarse tailings likely is the source of the higher LAA concentrations detected in surface water and sediment at FC-Pond and FC-2 locations (relative to the LAA concentrations in the upstream FC-1 location, which does not receive runoff from the coarse tailings).
- The higher LAA concentrations in the FC-Pond surface water and sediment relative to the upstream and downstream sampling locations may indicate that LAA accumulates in the pond, possibly as a result of the negligible flow rates in the pond relative to the stream, which allows the suspended LAA to settle in the pond. The variable LAA concentrations in the coarse tailings may also influence the detected LAA concentrations in the surface water and sediment in Fleetwood Creek.

5.2.4.3 Carney Creek

This evaluation of Carney Creek surface water and sediment includes sample data from the creek, Carney Pond, and several seeps that discharge near the base of the waste rock piles located to the north of Carney Creek. Surface water data for maximum LAA concentrations (>10 µm) per sample location are presented on **Figure 5-4a**.

Carney Creek Surface Water.
Seeps. A total of 21 samples were collected from seven seep locations as shown on **Table 5-17a** and **Figure 4-3a**. The concentrations of LAA >10 µm in these seep surface-water samples ranged from 0 MFL to 32 MFL, with a mean of 3.4 MFL. The highest mean LAA concentrations were detected at seep locations CCS-1 (mean LAA concentration of 12 MFL), CCS-6 (mean LAA concentration of 5.8 MFL), and CCS-14 (mean LAA concentration of 3.2 MFL). LAA concentrations also were higher in sediment samples collected at locations CCS-1 and CCS-6 (see **Table 5-18b, Panel A**; sediment results are discussed below). However, LAA concentrations were elevated in the sediment samples collected at locations CCS-8, CCS-9, and CCS-16, whereas the LAA concentrations in the surface water samples collected at CCS-8, CCS-9, and CCS-16 were relatively low (maximum detected LAA concentrations at these locations ranged from 0.05 MFL to 1.2 MFL, respectively). This indicates that there is not a consistently strong correlation between LAA concentrations in the surface water and sediments collected from the same seep locations.

Creek and Pond. The five Carney Creek sampling locations (including Carney Pond, CC-Pond), as well as time series graphs of LAA concentrations and flow rates, are shown in **Figure 5-6a**. A general correlation between flow rate and LAA concentrations can be seen at sample location CC-2. The limited data set at CC-1, CC-3A, and CC-3B preclude meaningful evaluation, but are suggestive of a correlation between flow rate and LAA concentrations. Flow versus LAA concentration relationships were not evaluated at the CC-Pond sampling station because flow in the pond is expected to be negligible. As shown on **Table 5-17a**, of the 72 surface water samples

collected within the creek (including within CC-Pond) at five stations, the concentrations of LAA >10 µm range from 0 MFL to 26 MFL with a mean of 1.9 MFL. The sample with the maximum concentration of LAA (26 MFL) was collected on September 20, 2011 at CC-2. Because this concentration did not correspond with an increase in flow rate at CC-2, this location was resampled on November 9, 2011, which resulted in a concentration of 0 MFL therefore, the 26 MFL result is considered anomalous and may be a result of sediment in the sample from sample collection methods. Therefore, discounting the 26 MFL result, the maximum concentration of LAA >10 µm is 7.5 MFL (also at CC-2).

Figure 5-6b shows the sampling locations, summary statistics, and the elevation of each sampling location for Carney Creek. The maximum concentrations of LAA >10 µm collected from upstream to downstream sample locations within Carney Creek are as follows:

- CC-3B: 0.12 MFL
- CC-3A: 1.9 MFL
- CC-1: 0.44 MFL
- CC-Pond: 6.6 MFL
- CC-2: 26 MFL (as discussed above, this result is likely due to a sample collection anomaly and is not considered representative of surface water concentrations at CC-2 as confirmed by the opportunistic sample collected on November 9, 2011).

Based on the data presented in **Table 5-17b** and shown on **Figure 5-6b**, MCL exceedances for LAA occur only at sampling station CC-2, located near the confluence with Lower Rainy Creek. LAA MCL exceedances are recorded in only three of 39 samples (8%) in CC-2. LAA concentrations in surface water increase between CC-1 and CC-Pond and continue to increase between CC-Pond and CC-2. Several factors likely account for this observed increase in LAA >10 µm including:

- Upper Carney Pond is in contact with the toe of the waste rock pile along the entire north perimeter and the slope to the south of the creek near upper Carney Pond is composed of native glacial till material (MWH, 2016a).
- Segments of lower Carney Creek below Carney Pond were observed to be confined on both sides by native till material, which contains naturally occurring LAA (MWH, 2016a).
- Mica flakes were observed during the site reconnaissance (MWH, 2016a) in the vicinity of CC-2. Mica is commonly collocated with LAA.
- Multiple seeps with elevated LAA concentrations flow into Carney Creek.
- Settling of LAA transported into the pond from upstream reaches. The higher LAA concentrations in the CC-Pond surface water relative to the upstream sampling locations suggests that LAA accumulates in the pond, possibly through settling of LAA transported to the pond from upstream reaches. Although flow rates were not measured in the pond, it is expected that the flow rate in the pond is negligible compared to the flow rates in the stream.
- The slope between CC-Pond and CC-2 is higher than the rest of the reach (see **Figure 5-6b**) which may attribute to the higher concentrations of LAA at CC-2 due to increased energy and erosion (of both the waste rock pile and native glacial till materials) that would be associated with higher flow velocities. LAA may be accumulating in CC-Pond from contributions of upstream sources as well as from

the waste rock pile and the native glacial till materials (sediment data are discussed below).

Carney Creek Sediment.

Seeps. As shown on **Tables 5-18a, Panel A** (by surface water area) and **5-18b, Panel A** (by station), a total of 21 sediment samples were collected and analyzed for fine-fraction (PLM-VE) LAA from seven seep sample locations along Carney Creek. The LAA concentrations in the seep sediment samples included:

- Bin B1 (trace; detected LAA <0.2%): 2 samples from 2 different locations
- Bin B2 (≥0.2% to <1%): 7 samples from 5 different locations
- Bin C (≥1%): 12 samples from 5 different locations

The highest (i.e., Bin C) fine-fraction (PLM-VE) LAA detections were located at CCS-1, CCS-6, CCS-8, CCS-9, and CCS-16.

Creek and Pond. As shown on **Tables 5-18a, Panel A** and **5-18b, Panel A**, a total of 37 sediment samples were collected and analyzed for fine fraction LAA in sediment (PLM-VE) from nine Carney Creek sample locations (including Carney Pond). The maximum fine fraction (PLM-VE) LAA concentrations from upstream to downstream sediment sample locations within Carney Creek are as follows:

- CC-1: Bin C (7%)
- CC-Pond: Bin C (10%)
- CC-2: Bin B2 (≥0.2% to <1%)

One of the 20 fine fraction LAA sample results for CC-1 is Bin B2 (≥0.2% to <1%) and the remaining 19 samples are Bin C (≥1%). All three fine fraction LAA sample results for CC-2 are either Bin B1 (trace; detected LAA <0.2%) or Bin B2 (≥0.2% to <1%). Samples in Carney Pond ranged from Bin B1 (trace; detected LAA <0.2%) to Bin C (≥1%). A total of 14 sediment samples were collected from six distinct locations within Carney Pond (see **Figure 5-4b** for sediment sample locations) and seven samples were Bin B1 (trace; detected LAA <0.2%), three samples were Bin B2 (≥0.2% to <1%), and four samples were Bin C (≥1%). All four Bin C sample results within Carney Pond were collected from either location CC-Pond (three samples) or CC-POND-1 (one sample), which are both along the northern bank adjacent to the waste rock pile. CC-Pond has the highest mean concentration at 6% by mass, whereas CC-1 and CC-2 have mean concentrations of 4% and 0.5% by mass, respectively.

As with the surface water data discussed above, the source of the LAA detected in the sediment in the Carney Creek and Carney Pond samples likely has multiple sources (e.g., presence of mica flakes, which are commonly collocated with LAA in the creek, seep contributions, contact with the waste rock pile, and/or native glacial till material). The higher fine fraction (PLM-VE) LAA in the sediment in Carney Pond relative to the stream sampling locations likely are a result of the difference in flow-rate between the pond and the creek (which allows LAA to settle out in sediments in the pond), or due to contact with waste rock or native alluvial fill materials.

The material surrounding Carney Creek (and surrounding Lower Rainy Creek as discussed below) is predominantly composed alluvial and glacial type deposits, which consist of light to dark, greenish-gray, fine to coarse sand and silty sand with gravel of varying lithologies, and with visible

mica flakes (MWH, 2016a). Naturally occurring LAA within the glacial deposits would also be expected to contribute to LAA in surface water along Carney Creek.

5.2.4.4 Summary of the Nature and Extent of LAA in Carney Creek Surface Water and Sediment

The data regarding LAA in Carney Creek surface water and sediment are summarized below.

- MCL exceedances for LAA in surface water occur only at sampling station CC-2, located near the confluence with Lower Rainy Creek. LAA MCL exceedances were recorded in only three of 39 surface water samples in CC-2. It is unlikely that the highest surface water concentration in CC-2 of 26 MFL is representative of true concentrations at this location and likely due to sampling error. Elevated LAA concentrations also were detected in several seep surface water samples.
- LAA concentrations were measured at progressively higher levels in surface water between CC-1, CC-Pond, and CC-2. Several factors are likely influencing the LAA concentration levels in Carney Creek including: contributions of LAA from the naturally occurring surficial geology, portions of Carney Creek and Carney Pond contacting the waste rock piles, contributions form seeps that discharge from the base of the waste rock piles, LAA accumulating in Carney Pond, and erosional effects as a result of the steeper slope along this reach.
- Fine-fraction LAA was detected in all sediment samples collected from the seep, creek and pond sampling locations in the Carney Creek drainage. As with the surface water, the source of the LAA detected in the sediment in the Carney Creek and Carney Pond samples likely has multiple sources (e.g., presence of mica flakes in the creek, seep contributions, contact with the waste rock pile and native glacial till material, changes in flow velocity between the creek and pond).
- The detected LAA concentrations in the surface water and sediment samples collected at the seep locations were among the highest detected in the OU3 Study Area. This suggests that waste rock piles (which overlie the seeps) may have the most significant mine-related impacts to OU3 Study Area surface water and sediment with regards to LAA concentrations. Naturally occurring geologic materials also may be a source of detectable LAA in Carney Creek.

5.2.4.5 Rainy Creek

Rainy Creek includes four distinct areas that will be discussed independently due to their varied location, LAA concentrations, and potential sources of LAA contributing to sample concentrations. These areas include: Upper Rainy Creek, Tailings Pond Area, KDID Toe Drains, and Lower Rainy Creek. East Tub Gulch is a tributary drainage that contributes flow to Lower Rainy Creek and is discussed in this section as well. Other potential sources of LAA in Rainy Creek include mine waste, which was reportedly placed into Rainy Creek prior to initiation of the wet mill process, and naturally occurring materials within the creek bed. The nature and extent of LAA in surface water and sediment will be discussed in each of these areas separately. This section also includes a discussion of the pore water sampling performed in Rainy Creek as described in **Sections 4.2.6** and **4.2.8.** Surface water data for maximum LAA concentrations (>10 µm) per sample location are presented on **Figure 5-4a**.

Upper Rainy Creek Surface Water. The three Upper Rainy Creek sampling locations (URC-1, URC-1A, URC-2) and the associated time series graphs of LAA concentrations and flow rates are shown on **Figure 5-7a**. No correlation between flow rate and LAA concentrations is evident at

URC-1 (not shown on **Figure 5-7a** because all surface water concentrations were non-detect) or URC-1A. This is attributable to a lack of impact from mining activities and naturally occurring LAA at these sampling locations. Correlation between flow rate and LAA concentrations can be seen at sample location URC-2. As shown on **Table 5-17a**, of the 48 surface water samples collected within the Upper Rainy Creek at three locations, the concentrations of LAA >10 µm range from 0 MFL to 6.6 MFL with a mean of 0.21 MFL.

Figure 5-7c shows the sampling locations, summary statistics, the maximum and mean concentrations, and the elevation of each sampling location for Upper Rainy Creek. The maximum concentrations of LAA >10 µm collected from upstream to downstream sample locations within Carney Creek are as follows:

- URC-1: 0 MFL
- URC-1A: 0.05 MFL
- URC-2: 6.6 MFL

Based on the data presented in **Table 5-17b** and shown in **Figure 5-7c,** no MCL exceedances for LAA occur along Upper Rainy Creek. LAA concentrations increase with proximity to disturbed areas of the mine and with distance from the headwaters. An increase in LAA concentration is evident between URC-1A and URC-2. The slope between sample location URC-1A and URC-2 does not appear to be a factor in contributing to higher concentrations of LAA at URC-2, since the grade between these two sampling points is gradual. URC-2 has elevated LAA concentrations when compared to upstream sampling points, which is potentially indicative of disturbance due to mining activities. The creek also may be intercepting naturally occurring materials with higher concentrations of LAA.

Upper Rainy Creek Sediment. As shown on **Table 5-18a, Panel A** (by surface water area) and **Table 5-18b, Panel A** (by station), a total of 10 sediment samples were collected and analyzed for fine fraction LAA (PLM-VE) from three sample locations in Upper Rainy Creek (see **Figure 5-4b)**. The maximum LAA concentrations from upstream to downstream sediment sample locations within Upper Rainy Creek are as follows:

- URC-1: Bin A (ND)
- URC-1A: Bin B1 (trace; detected LAA $\leq$0.2%)
- URC-2: Bin B2 ($\geq$0.2% to <1%)

Three of the four sample results for URC-2 are Bin B1 (trace; detected LAA <0.2%), while the fourth sample is Bin B2 ($\geq$0.2% to <1%). Samples in URC-1A ranged from Bin A (ND) (2 samples) to Bin B1 (trace; detected LAA <0.2%) (1 sample). All three URC-1 samples were Bin A (ND). URC-2 has the highest mean concentration at 0.3% by mass, whereas URC-1 and URC-1A have mean concentrations of 0.03% and 0.1% by mass, respectively.

Similar to the surface water data at URC-2 discussed above, the source of the LAA detected in the sediment at URC-2 is potentially indicative of disturbance due to mining activities and the creek may be intercepting naturally occurring materials with higher concentrations of LAA.

Tailings Pond Area Surface Water. The four Tailings Pond Area sampling locations (UTP, TP, TP-Overflow, and TP-Overflow-A) as well as a time series graph of LAA concentrations and flow rates for TP-Overflow are shown in **Figure 5-7a**. A correlation between flow rate and LAA concentrations is evident at TP-Overflow. Flow data is not applicable at the UTP and TP sampling

locations as they are located in the Tailings Ponds where flow is expected to be negligible relative to the adjacent streams. TP-Overflow-A does not have recorded flow data due to lack of water. As shown on **Table 5-17a**, of the 74 surface water samples collected within the Tailings Pond Area, the concentrations of LAA >10 µm range from 0 MFL to 50 MFL with a mean of 4.8 MFL.

Figure 5-7c shows the sampling locations, surface water summary statistics, the max and mean concentrations, and the elevation of each sampling location in the Tailings Pond Area. The maximum concentrations of LAA longer than 10 µm in length collected from upstream to downstream sample locations within the Tailings Pond Area are as follows:

- UTP: 4.5 MFL
- TP: 50 MFL
- TP-Overflow: 0.79 MFL
- TP-Overflow-A: 0 MFL

Based on the data presented in **Table 5-17b** and shown in **Figure 5-7c,** MCL exceedances for LAA in the Tailings Pond Area surface water occur only at sampling location TP. LAA MCL exceedances are recorded in 11 of 56 samples (20%) in sample location TP. The maximum LAA concentrations at sample location TP reduced during the years it was sampled with the maximum recorded concentration at sample location TP in the year 2008 at 50 MFL of LAA >10 µm. This was followed by sampling in 2011, 2012, and 2015 with maximum concentrations of LAA >10 µm of 28 MFL, 19 MFL, and 3.5 MFL, respectively. It should be noted that the Former Mine Area had relatively low spring runoff volumes in 2015. However, these reductions in concentrations at sample location TP could be a result of cleaner sediments being flushed down both Upper Rainy Creek and Fleetwood Creek covering the more highly impacted sediment materials within the Tailings Pond. The key factor likely influencing the historically elevated concentrations of LAA >10 µm at sample location TP is its historical use as a tailings pond for the mine and its location at the base of the coarse tailings pile.

Tailings Pond Area Sediment. As shown on **Tables 5-18a, Panel A** (by surface water area) and **5-18b, Panel A** (by station), a total of 38 sediment samples were collected and analyzed for fine fraction LAA (PLM-VE) in sediment from 19 sample locations (see **Figure 5-4b**). On average two samples were taken from each sample location. All sample results had detections; 14 samples were Bin B1 (trace; detected LAA ≤0.2%), 19 samples were Bin B2 (≥0.2% <1%), and five samples were Bin C (≥1%). The Bin C detections were spread out across the pond on both the northwest (1.5% at TP and 2% at TP-4) and the southeast banks (2% at TP-3) as well as near the middle of the pond (2% at TP-7 and 1% at TP-10).

Similar to the surface water data discussed above, the key factor likely influencing the concentration of LAA in sediment at the Tailings Pond Area is its historical use as a tailings pond for the mine and its location at the base of the coarse tailings pile.

KDID Toe Drains Surface Water. A total of 70 surface water samples were collected from 12 KDID toe drain locations (sample locations D-1 through D-12 shown on **Figure 5-4a**). As shown on **Tables 5-17a** and **5-17b,** the concentrations of LAA >10 µm in these surface water samples ranged from 0 MFL to 0.41 MFL, with a mean of 0.022 MFL (all well below the MCL). The low levels of LAA in the KDID Toe Drains and in Lower Rainy Creek just below the KDID are likely due to combination of low permeability materials in the impoundment and contribution of un-impacted groundwater to toe drain flow. Inflow of groundwater into both the KDID Toe Drains and

Lower Rainy Creek just below the KDID would be expected to reduce LAA concentrations within the toe drain water.

The KDID embankment materials and fine tailings have low hydraulic conductivities compared to underlying alluvial materials. Consequently, the primary source of water in the toe drains during low or base flow conditions is likely the alluvium beneath the fine tailings materials. To better understand the flow regime within and around the KDID, surface water flow measurements were made within all of the creeks and toe drains in and around the KDID in spring 2015 (this is the subject of a forthcoming report). Based on flow measurements, flow rates increase by more than 50% in most instances in Rainy Creek below the KDID compared to the combined flows from Upper Rainy and Fleetwood Creeks. These data indicate that this interval, just below the KDID, is likely a gaining portion of Lower Rainy Creek during high flow periods. Further evidence of this are the multiple seeps and locations of standing water observed in the Rainy Creek Valley between the KDID and the Mill Pond during springtime. Flows measured in Lower Rainy Creek just below the Mill Pond (LRC-2) are approximately the same as flows measured in Lower Rainy Creek just above the confluence with the Kootenai River (LRC-6) over the spring 2015 sampling period, indicating a relatively small contribution from runoff from the lower portion of the drainage basin during this timeframe. It should be noted that there were no significant (more than 0.3 inch as measured at Libby Ranger Station) precipitation events recorded within this sampling period so surficial runoff is expected to be a relatively minor contribution to the measured surface flows.

Based on the results of the geochemical evaluation of surface water and groundwater (see **Section 2.9**) and on the above findings, groundwater is expected to be a significant contributor to flow both in the KDID Toe Drains and in Lower Rainy Creek below the KDID. It has been demonstrated that LAA levels in surface water are directly related to flow velocity. Given the low seepage velocity and natural filtration that typically occurs in porous aquifers, it is expected that very little transport of LAA would occur within groundwater. The lack of significant LAA levels detected in groundwater samples (see **Section 5.2.3**), supports this assumption. Therefore, inflow of groundwater into both the KDID Toe Drains and Lower Rainy Creek just below the KDID would be expected to reduce LAA concentrations in these areas and within the toe drain water.

KDID Toe Drains Sediment. No sediment samples were collected at the toe drain locations.

East Tub Gulch Surface Water. East Tub Gulch is tributary drainage located to the northwest of Lower Rainy Creek, which enters Lower Rainy Creek downstream of LRC-5 (see **Figures 4-1a**, **5-7b**, and **5-7c**). The ponds at the mouth of this creek are referred to herein as the East Tub Gulch Ponds. It should be noted that U.S. Geological Survey (USGS) maps reference Tub Gulch as a drainage located to the west of Rainy Creek, discharging directly into the Kootenai River, and located outside of the Rainy Creek drainage basin. The small tributary drainage northwest of Lower Rainy Creek has been referenced as East Tub Gulch herein to differentiate it from the USGS map showing Tub Gulch, and to account for previous documents referring to the tributary creek Tub Gulch.

A total of 12 surface water samples were collected from two locations in East Tub Gulch and analyzed for LAA; one in East Tub Gulch creek (East-TGC) and one in the East Tub Gulch pond (East-TGP) (see **Tables 5-17a** and **5-17b**). The concentrations of LAA >10 µm in these 12 surface water samples ranged from 0 MFL to 0.78 MFL, with a mean of 0.17 MFL (all well below the MCL). These results suggest that surface water in East Tub Gulch is not adversely impacted by historical mining activities or the presence of mine wastes, and that the East Tub Gulch drainage is not contributing significant amounts of LAA to Lower Rainy Creek.

East Tub Gulch Sediment. No sediment samples were collected in East Tub Gulch.

Lower Rainy Creek Surface Water. The 11 Lower Rainy Creek sampling locations, as well as time series graphs of LAA concentrations and flow rates for locations with flow data, are shown in **Figures 5-7a** and **5-7b**. A general correlation between flow rate and LAA concentrations can be seen in graphs with sufficient data for evaluation (e.g., TP-TOE1, LRC-2, LRC-6, etc.). Flow data is not applicable at the Mill Pond (MP) sampling location because flow is expected to be negligible relative to the adjacent streams. As shown on **Table 5-17a**, of the 263 surface water samples collected within the creek (including the pond) from the 11 locations, the concentrations of LAA >10 µm range from 0 MFL to 66 MFL, with a mean of 3.0 MFL.

Figure 5-7c shows the sampling locations, summary statistics, the max and mean concentrations, and the elevation of each sampling location for Lower Rainy Creek. The maximum and mean concentrations of LAA >10 µm collected from upstream to downstream sample locations within Upper Rainy Creek are presented below respectively:

- TP-TOE1: 1.6 MFL and 0.35 MFL
- TP-TOE1A: 0.25 MFL and 0.074 MFL
- TP-TOE2: 1.2 MFL and 0.4 MFL
- MP: 10 MFL and 1.1 MFL
- LRC-1: 7.5 MFL and 1.1 MFL
- LRC-2: 9.0 MFL and 1.7 MFL
- LRC-2A: 4.2 MFL and 2.9 MFL
- LRC-3: 2.6 MFL and 1.2 MFL
- LRC-4: 8.3 MFL and 3.4 MFL
- LRC-5: 13 MFL and 3.9 MFL
- LRC-6: 66 MFL and 6.9MFL

Based on the data presented in **Table 5-17b** and shown in **Figure 5-7c,** MCL exceedances for LAA occur in 25 of 263 samples (10%) from TP-TOE1 to LRC-6. Six of the 11 Lower Rainy Creek sampling locations have results with MCL exceedances. In general, the mean concentration of LAA in surface water increases with distance from the KDID.

A comparison of LAA concentration test results and surface water flow rates at LRC-2 and LRC-6 indicates a general correlation between higher flow rates and LAA concentrations above the MCL, particularly at LRC-6.

Evaluation of the maximum concentrations of LAA measured indicates a possible increase or additional contribution of LAA in surface water between LRC-5 and LRC-6. It should be noted that slopes along the alignment of Rainy Creek are flatter above LRC-4 (typically between 1% and 5% grade), begin to increase in slope between LRC-4 and LRC-5, and are steepest between LRC-5 and LRC-6 (typically between 5% and 10% grade, but up to 19.5% in places). This indicates that the higher LAA readings at LRC-6 are related to increased energy and erosion that would be associated with higher flows.

Lower Rainy Creek Sediment. As shown on **Tables 5-18a, Panel A** (by surface water area) and **5-18b, Panel A** (by station), a total of 58 sediment samples were collected and analyzed for fine fraction LAA (PLM-VE) from 14 sample locations (two at the toe of the KDID, six at the Mill Pond, and six along the length of Lower Rainy Creek) (see **Figure 5-4b** for locations). The results

indicated detections of LAA in all samples; 11 samples were Bin B1 trace; detected LAA <0.2%), 17 samples were Bin B2 (≥0.2% to <1%), and 30 samples were Bin C (≥1%). The Bin C detections were spread out along the length of Lower Rainy Creek. The highest mean concentration at 10% by mass occurred at TP-TOE2.

During the Vermiculite Removal operation conducted in 2012 and the summer of 2013, vermiculite material was noted in what was classified as "native soils" that extended to the banks of Lower Rainy Creek. LAA-bearing materials in sediment and within native soils adjacent to Lower Rainy Creek would be expected to contribute to LAA in surface water during higher flow periods.

The material surrounding Carney and Lower Rainy Creeks is predominantly composed of similar alluvial and glacial type deposits as those observed in the test pit investigation program (MWH, 2016a). Light to dark, greenish-gray, fine to coarse sand and silty sand with gravel of varying lithologies and with visible mica flakes were observed in the creek bed over the length of Lower Rainy Creek. In addition, based on field observations, Lower Rainy Creek appears to be down-cutting into underlying glacial material. Naturally occurring LAA within the glacial deposits would be expected to contribute to LAA in surface water along this stretch of Rainy Creek.

Vermiculite materials were also observed in discrete piles, embankment fills at the Mill Pond and East Tub Gulch ponds, general fill materials (particularly down-gradient of the KDID), within pipe backfill and road fill, and in overbank and alluvial deposits along the majority of Lower Rainy Creek. All of these vermiculite materials (which may be collocated with LAA-bearing materials), in addition to the naturally occurring materials within the basin, would be expected to have the potential to contribute LAA to surface water.

Rainy Creek Pore Water. Pore water samples were collected during the Phase V Part B investigations to support the ecological risk assessment. The pore water inside the Whitlock-Vibert box (Pore Water [In]) and gravel pore water (outside the box) (Pore Water [Out]) were measured as discussed in **Section 4.2.6**. LAA concentrations in pore water samples are provided in **Appendix E**. All pore water LAA sampling locations are co-located with sediment sampling locations as presented on **Figure 5-4b**.

For Pore Water [In], samples were collected from LRC-2, LRC-4, LRC-5, URC-2, and NSY-RI. LAA >10µm ranged from 0.63 MFL to 485 MFL in the LRC locations with a mean concentration of 47 MFL, 0 MFL to 1.8 MFL in the URC location, and) MFL to 1.7 MFL in the NSY reference location. Total LAA concentrations ranged from 5 MFL (LRC-2) to 3,434 MFL (LRC-4) in the LRC locations with a mean concentration of 299 MFL, 0 MFL to 22 MFL in the URC location, and 0 MFL to 21 MFL in the NSY reference location.

For Pore Water [Out], samples were collected from LRC-2, LRC-4, and LRC-5. LAA longer than 10µm in length ranged from 13 MFL to 415 MFL with a mean concentration of 201 MFL and total LAA concentrations ranged from 242 MFL to 2,700 MFL with a mean concentration of 1315 MFL. The total LAA concentrations increased in a downstream direction from LRC-2 to LRC-5; however, the LAA >10µm did not exhibit this same increasing trend.

It should be noted that pore water sample concentrations were highly variable across replicate samples and across samples collected during the sample durations. The variability of the results is potentially due to the difficulties noted in the sample collection process, which resulted in the presence of variable amounts of sediment in the pore water samples (CDM Smith, 2016).

5.2.4.6 Summary of the Nature and Extent of LAA in Rainy Creek Surface Water and Sediment

The data regarding LAA in Rainy Creek surface water and sediment are summarized below.

General Findings

- It can be generally concluded that flow rate and creek slope directly affect LAA concentrations in surface water.
- Pond sediments (Fleetwood Pond, Carney Pond, Tailings Pond, and Mill Pond) accumulate LAA due to a reduction in stream velocity, which allows the suspended LAA to settle. During storm events, re-suspension of LAA in sediments could potentially increase LAA concentrations in surface water.
- Both naturally occurring and mine disturbances are contributing to LAA concentrations in surface water and sediment.

Upper Rainy Creek

- No MCL exceedances for LAA in surface water occur along Upper Rainy Creek.
- LAA concentrations in surface water and sediment increase with proximity to the disturbed areas of the mine.

Tailings Pond Area

- MCL exceedances in surface water only occur at the TP pond sampling location in 20% of the samples collected.
- The maximum concentrations of LAA >10 µm in surface water are reducing in magnitude over time at sample location TP.
- The predominant factor likely influencing the elevated concentrations of LAA in sediment at the Tailings Pond Area and at surface water sampling location TP is its historical use as a tailings pond for the mine and its location at the base of the coarse tailings pile.

KDID Toe Drains

- The low levels of LAA in the KDID Toe Drains and in Lower Rainy Creek just below the KDID are likely due to an influx of unimpacted groundwater in the area. The lack of significant LAA levels detected in groundwater samples would be expected to reduce LAA concentrations in these areas and within the toe drain samples.

East Tub Gulch

- No MCL exceedances for LAA in surface water occur in East Tub Gulch.
- Surface water results suggest the East Tub Gulch drainage is not contributing significant amounts of LAA to Lower Rainy Creek.

Lower Rainy Creek

- Surface water sample analyses indicate exceedances of the MCL at various sampling locations occurring typically between the months of April and May, with maximum concentrations up to 66 MFL >10 µm at LRC-6. Samples obtained from LRC-6 contained more frequent exceedances of the MCL compared to the other Lower Rainy Creek locations. A comparison of LAA concentration test results and surface water flow rates at LRC-2 and LRC-6 indicates a general correlation between higher flow rates and LAA concentrations above the MCL, particularly at

LRC-6. The higher LAA concentrations at LRC-6 are related to increased energy and erosion associated with higher flows and steeper gradients.
- LAA-bearing materials in sediment and within native soils adjacent to Rainy Creek would be expected to contribute to LAA in surface water during higher flow periods.
- Lower Rainy Creek appears to be down-cutting into underlying glacial material. Naturally occurring LAA within the glacial deposits would be expected to contribute to LAA in surface water along this stretch of Rainy Creek.

5.2.4.7 Kootenai River

Kootenai River Surface Water. As shown on **Tables 5-17a** (by surface water area) and **5-17b** (by station), a total of 73 surface water samples were collected from 19 locations in the Kootenai River over a length of the river of approximately 33 miles (see **Figure 4-1a** and **Figure 5-4a**). Concentrations of LAA >10 µm in these surface water samples ranged from 0 MFL to 0.098 MFL, with a mean of 0.0063 MFL (all well below the MCL of 7 MFL).

Given the periodic elevated LAA levels that have been detected in surface water in Rainy Creek (discussed in **Section 5.2.4.5**), particularly during high flow events, Rainy Creek is a potential contributor to the presence of LAA in the Kootenai River. However, evaluation of the magnitude of the Rainy Creek contribution is confounded by the number of other potential sources of LAA within the Libby Site boundary that are not associated with the OU3 Study Area (including both historical and present-day activities). These other potential sources of LAA to the Kootenai River are briefly summarized below, depicted on **Figure 5-8**, and discussed in greater detail in **Section 2.11.1.3**. These include:

- Materials containing naturally occurring LAA, which have been observed within the Kootenai Valley.
- Operations at the former Export Plant (OU1), which was located immediately adjacent to the Kootenai River and managed vermiculite concentrate (over 350,000 tons during a 4-year period) for at least 30 years.
- The former Screening Plant at OU2, which managed over 6,600,000 tons of vermiculite concentrate on the east side of the Kootenai River. Concentrate was size-sorted and transported from this location by a conveyor bridge system across the river to the rail load-out system on the other side of the river adjacent to the Burlington Northern Rail Lines. Records indicate that the Screening Plant conveyor system collapsed into the Kootenai River (see **Figure 2-18**) in 1979 due to a train derailment where derailed freight cars hit the loading facility (Missoulian, 1979; Western News, 1979).
- Based on investigations and evaluations conducted as part of the OU4 RI, many properties adjacent to the Kootenai River required response actions due to LAA impacts, including the Bluffs area. Additionally, four creeks (Flower Creek, Granite Creek, Pipe Creek, and Libby Creek), all tributaries of the Kootenai River, required removal actions due to agency placement of LAA-impacted riprap along the stream channels. Subsequently, over 6,800 cubic yards and 115 truckloads of contaminated soil and riprap material were removed from the four Kootenai River tributaries.

The Rainy Creek confluence with the Kootenai River is over two miles from the Former Mine Area whereas the non-OU3 Study Area sources of LAA are significantly closer or, immediately adjacent to, the Kootenai River.

Sampling results indicate that LAA discharged into the Kootenai River from various sources has not resulted in significant LAA concentrations in the Kootenai River surface water, likely because the large volume of water flowing in the Kootenai River dilutes the LAA concentrations. A comparison of average flows in the Kootenai River and Rainy Creek helps put the potential contributions from Rainy Creek in perspective. Measured flow in Lower Rainy Creek averaged 2.82 cfs at the LR-6 ISCO station between the years 2008 and 2015, and flow in the Kootenai River averaged 10,988 cfs at the USGS station (#12,301,933) located below the Libby Dam during that same period (0.025% contribution).

Kootenai River Sediment. As shown on **Tables 5-18a** (by surface water area) and **5-18b** (by station), a total of 20 sediment samples were collected and analyzed for fine fraction LAA (PLM-VE) from 20 sample locations. The LAA concentrations in the Kootenai River sediment samples included:

- Bin A (ND): 3 samples from 3 different locations
- Bin B1 (trace; detected LAA <0.2%): 10 samples from 10 different locations
- Bin B2 (≥0.2% to <1%): 7 samples from 7 different locations

The mean concentration of fine fraction LAA in sediment samples was 0.3% in mass.

In order to assess the distribution of LAA along the length of the Kootenai River, the fine fraction LAA in sediment (PLM-VE) is presented below for specific reaches of the Kootenai River; from sample locations upstream of the mouth of Lower Rainy Creek (URK-2) to downstream sample locations at the City of Troy (#25). The Kootenai River is assessed geospatially to focus on possible relationships with potential LAA source locations (as discussed in **Section 2.11.1**). One sediment sample was collected from each of the following locations as shown on **Table 5-18b**. **Figure 5-4c** depicts each of the sample location.

Upstream of the Mouth of Lower Rainy Creek. There is one upstream location (UKR-2) where sediment was collected and analyzed. The result of the sediment sample collected at UKR-2 was Bin A (ND).

Immediately Downstream of Lower Rainy Creek Mouth. There were six locations (KR-9, KR-10, KR-11, KR-12, KR-13, and KR-20) immediately downstream of the mouth of Lower Rainy Creek. The mouth of Lower Rainy Creek passes through OU2, where the former Screening Plant and Flyway were located. The results of the LAA analysis for these samples ranged from Bin A (ND for KR-12) to Bin B1 (trace; detected LAA <0.2% for KR-9, KR-10, KR-11, and KR-13), to Bin B2 (≥0.2% to <1% for KR-20). There appears to be very little accumulation of LAA in sediment near the mouth of Lower Rainy Creek.

Vicinity of Libby Creek and OU1. There were three locations (KR-21, #15-Kootenai River, and #16-Kootenai River) where sediment samples were collected and analyzed along this reach of the Kootenai River. The results of the LAA analysis ranged from Bin A (ND for #15-Kootenai River) to Bin B2 (≥0.2% to <1% for #16-Kootenai River and KR-21).

Downstream of OU1 Past the City of Troy. There are 10 locations (from #17-Kootenai River thru #26-Kootenai River) downstream from OU1 where sediment samples were collected and analyzed. This reach of the Kootenai River includes OU4, where Flower Creek, and Pipe Creek discharge into the Kootenai River. The results of the LAA analysis ranged from: Bin B1

(trace; detected LAA <0.2% for #17-Kootenai River, #20-Kootenai River, #22-Kootenai River, #23-Kootenai River, #25-Kootenai River, and #26-Kootenai River) to Bin B2 (≥0.2% to <1% for #18-Kootenai River, #19-Kootenai River, #21-Kootenai River, and #24-Kootenai River).

5.2.4.8 Summary of the Nature and Extent of LAA in Kootenai River Surface Water and Sediment

The data regarding LAA in Kootenai River surface water and sediment are summarized below.

- Seventy-three surface water samples were collected and analyzed for LAA at sample locations spread out over approximately 33 miles of the Kootenai River, starting upstream (UKR-2) of the mouth of Lower Rainy Creek to the City of Troy (#25-Kootenai River).
- There were no exceedances of the LAA MCL in any of the 73 water samples analyzed; the highest concentration of LAA >10µm was 0.098 MFL, with a mean concentration of 0.006 MFL.
- Twenty sediment samples were collected and the analyzed by the PLM-VE method for fine fraction LAA at sample locations between upstream of the Rainy Creek Mouth (UKR) to approximately 8 miles north-northeast of the City of Troy (#26-Kootenai River).
- The highest concentration of fine fraction LAA in the sediment samples was Bin B2 (≥0.2% to <1%); the mean concentration of fine fraction LAA in the sediment samples was 0.3% in mass.
- There are a number of potential sources (e.g., OU1, OU2, conveyor system, riprap in creeks, and natural material) that have contributed LAA to the Kootenai River that are not associated with the OU3 Study Area (historical or present day activities).
- There appears to be very little accumulation of LAA in sediment near the mouth of Lower Rainy Creek, which further supports the idea that contribution of LAA to the Kootenai River from Lower Rainy Creek, is not significant.

5.2.5 LAA Concentrations in Tree Bark, Duff Material, Ash and Smoke from the Forested Areas

The following presents a discussion of the nature and extent of LAA in tree bark, duff material, ash, and smoke from the forested area samples. For the purposes of evaluating the extent of LAA, EPA has directed that levels of tree bark, duff material, and ash be presented in terms of "total" structures (referred to in the appended tables as "Total LAA") as well as PCME LAA. "Total LAA" includes both asbestos and non-asbestiform analogues of the same amphiboles and often includes structures with widths and lengths outside the range that can be detected by PCM (total includes all structures with a length ≥0.5 µm and an aspect ratio ≥3:1). Because the LAA toxicity values were developed from epidemiologic studies that employed PCM for exposure determinations, PCME LAA is the measure most relevant for the purposes of human health risk assessment. Tree bark, duff material, ash and smoke data from forested area samples are provided in **Appendix E**. PCME and total LAA data for tree bark and duff in the vicinity of the Former Mine Area are also presented on **Figures 5-9a** and **5-9b,** respectively. PCME and total LAA data for ash are presented on **Figures 5-11**. Additionally, a discussion of LAA in ash and smoke is also presented below.

Tree Bark. **Tables 5-19a** (by distance from Former Mine Area center) and **5-19b** (by station) present summaries of LAA results for tree bark from the forested area. **Figures 5-9a** and **5-9b**

present sample locations for the maximum PCME and maximum total LAA detections in tree bark, respectively. Data are presented as a surface loading estimate (i.e., Ms/cm^2 of bark surface area). The EPA made these estimations by assuming that all particulate found in each bark sample was present on the surface. Surface areas were estimated based on the gross geometry of each sample; neither bark layer thickness nor bark roughness was measured.

Maximum concentrations were observed in the predominant wind direction towards the northeast (refer to **Figures 5-9a** and **5-9b** OU3 Study Area Wind Rose inset). PCME LAA tree bark levels ranged from 0 to 4.9 Ms/cm^2 (SL15-04) and total LAA tree bark levels ranged from 0 to 32 Ms/cm^2 (WA-Near). Both locations were within two miles from the center of the Former Mine Area. Tree bark data were grouped on **Table 5-19a** into near (within two miles from the center of the Former Mine Area), intermediate (between two and six miles from the center of the Former Mine Area), and far (more than six miles from the center of the Former Mine Area) data sets. As shown on **Table 5-19a**, maximum PCME LAA levels for the near, intermediate, and far data groupings were 4.9 Ms/cm^2 (SL15-04), 1.9 Ms/cm^2 (SL45-07), and 0.77 Ms/cm^2 (Location #20, sample location from the Nature and Extent Study, USACE, 2014b), respectively. Maximum total LAA levels for the near, intermediate, and far data groupings were 32 Ms/cm^2 (WA-Near), 8.8 Ms/cm^2 (SL255-06), and 2.6 Ms/cm^2 (Location #20), respectively. Primarily, PCME LAA and total LAA levels are highest within approximately two miles of the center of the mine area, within a northeast-trending area that correlates with the prevailing wind directions, and to the south southwest, as presented on **Figures 5-9a** and **5-9b**. PCME LAA levels for tree bark samples collected four or more miles from the center of the Former Mine Area were all less than 1 Ms/cm^2. Total LAA levels for tree bark samples collected six or more miles from the center of the Former Mine Area were all less than 3 Ms/cm^2. (Note: 1 Ms/cm^2 and 3 Ms/cm^2 are not risk-based thresholds, but are arbitrarily selected values to illustrate the relative magnitude of fiber levels in bark.)

Duff Material. **Tables 5-20a** (by distance from Former Mine Area center) and **5-20b** (by station) present summaries of LAA results for duff material from the forested area. **Figures 5-9a** and **5-9b** present sample locations for the maximum PCME and maximum total LAA detections in duff material, respectively. Results for LAA were reported on a dry weight basis as million structures per gram (Ms/g-dw) of duff material. Generally, like tree bark, LAA concentrations were higher in duff samples collected within two miles of the center of the former mine area within a northeast-trending area that correlates with the prevailing wind directions. In addition, one area to the west (SL255-04) of the mine center showed a relatively high duff concentration.

PCME LAA in duff samples ranged in concentration from 0 to 572 Ms/g-dw (SL75-03; within two miles from the center of the Former Mine Area) and total LAA in duff samples ranged in concentration from 0 to 3,200 Ms/g-dw (SL45-01; within two miles from the center of the Former Mine Area). Duff data were grouped on **Table 5-20a** into near (within two miles from the center of the Former Mine Area), intermediate (between two and six miles from the center of the Former Mine Area), and far (more than six miles from the center of the Former Mine Area) data sets. As shown on **Table 5-20a**, maximum PCME LAA levels for the near, intermediate, and far data groupings were 572 Ms/g-dw (SL75-03), 505 Ms/g-dw (SL255-04), and 10 Ms/g-dw (Location #19) and the maximum total LAA levels for the near, intermediate, and far data groupings were 3,200 Ms/g-dw (SL45-01), 2,200 Ms/g-dw (SL255-04), and 64 Ms/g-dw (SL75-15), respectively. As shown on **Figure 5-9a**, none of the intermediate samples collected beyond 2.5 miles from the mine center contained PCME duff levels greater than 100 Ms/g-dw. As shown on **Figure 5-9b**, none of the intermediate samples beyond 4.5 miles from the mine center contained total duff levels greater than 150 Ms/g-dw (SL45-08). (Note: 100 Ms/g-dw and 150 Ms/g-dw are not risk-based thresholds, but are an arbitrary selected value to illustrate the relative magnitude of LAA levels in duff.)

Ash and Smoke. As discussed in **Section 4.6.5**, the Simulated Open Burning of Duff Material investigation was performed in EPA's OBTF to examine the potential for smoke emissions of LAA from the simulated open burning of duff samples collected from the OU3 Study Area. Prior to being burned, the duff starting material was analyzed for LAA as well as characterized as fuel using proximate and ultimate analyses (EPA, 2012i). These measurements were combined with measurements of the mass of duff material burned and various flow rates through the OBTF to generate an estimate of emission factors of fibers per PM (LAA fibers per mass of duff material burned divided by $PM_{2.5}$ in terms of mass emitted per mass of duff burned). The emission factors were combined to yield estimates of LAA fibers per mass of $PM_{2.5}$. This modified emission factor was used by the EPA to perform an exposure assessment of firefighting personnel and Libby residents that might be subjected to inhalation exposures of LAA fibers should a wildfire occur in the vicinity of the Former Mine Area (EPA, 2013e,f) (refer to **Section 6.1.2.6**). Under the conditions that were tested, fractions of PCME asbestos fibers (the asbestos fibers that meet the dimensional characteristics to be of health concern) ranging from 88% to 105% (average = 92%) appear to remain behind in the residual bottom ash after the burn was completed for the High Temperature burn conditions and fractions of PCME asbestos fibers ranging from 88% to 115% (average = 99%) appear to remain behind in the residual bottom ash after the burn was completed for the Low Temperature burns. Calculated results greater than 100%, were mostly due to analytical variability between sampled media (e.g., LAA in ash, LAA in duff). These observations suggest that the majority of the LAA fibers that are present in the duff do not become entrained into the air (smoke) emissions, but remain in the ash after the duff material is burned. The complete data for this investigation are presented in the *Emissions of Amphibole Asbestos from the Simulated Open Burning of Duff material from Libby, MT* (EPA, 2012i).

Additional tree bark, duff material, and ash samples have been collected and analyzed for LAA as part of specific ABS investigations for the OU3 Study Area RI. Because these samples were collected in conjunction with an ABS event, these data are discussed and presented below in the ABS **Section 5.2.7**.

5.2.5.1 Summary of the Nature and Extent of LAA in Tree Bark, Duff Material, Ash and Smoke

The data regarding LAA in tree bark, duff material, ash, and smoke are summarized below.

- Generally, PCME LAA levels were highest within tree bark and duff closest to the Former Mine Area and within a northeast-trending area that correlates with the prevailing wind directions. The mean PCME LAA levels for tree bark for the near, intermediate, and far data groupings were 0.74 Ms/cm^2, 0.22 Ms/cm^2, and 0.049 Ms/cm^2, respectively. The mean total LAA levels for tree bark for the near, intermediate, and far data groupings were 3.7 Ms/cm^2, 0.88 Ms/cm^2, and 0.17 Ms/cm^2, respectively.
- The mean PCME LAA levels for duff samples from the near, intermediate, and far data groupings were 141 Ms/g-dw, 18 Ms/g-dw, and 1.2 Ms/g-dw, respectively. The mean total LAA levels for duff samples from the near, intermediate, and far data groupings were 733.7 Ms/g-dw, 78.8 Ms/g-dw, and 6.8 Ms/g-dw, respectively.
- These data indicate LAA levels in tree bark and duff material tend to decrease with increasing distance from the Former Mine Area. The highest LAA levels are generally within 3 to 4 miles of the mine center.
- Results of controlled burn tests using LAA-impacted duff and firewood from the OU3 Study Area indicate the majority (>90%) of the LAA fibers present in the

media that is burned do not become entrained in air emissions, but are retained in the ash.

5.2.6 Ambient Air

As described in **Section 4.7**, ambient air samples were collected as part of the OU3 Study Area RI during fall 2007 and summer and fall 2008. LAA data in ambient air near the Former Mine Area were collected at 12 sampling stations (see **Figure 5-10**). One round of sampling (four sequential 5-day samples) was performed during the month of October 2007, and a second round (8 sequential 5-day samples) was collected in the interval from July to October 2008 (EPA, 2008b). The relatively long sampling duration (five days) was used to provide assurance that the samples were representative of long term average concentrations.

Ambient air sample results for LAA are provided in **Appendix E** and are summarized on **Table 5-21a** (by season) and **5-21b** (by station). Ambient air sample locations and maximum PCME LAA detections are shown on **Figure 5-10.**

As shown on **Tables 5-21a** and **5-21b**, PCME LAA levels in ambient air ranged from ND to 0.0056 structures per cubic centimeter (s/cc). As shown on the wind rose on **Figure 5-10**, the prevailing wind direction is to the northeast in the area. However, the highest mean concentration of PCME LAA in ambient air was reported at Station A-9 (0.0056 s/cc), which is located south, or upwind of the prevailing wind direction, from the mine. As shown on **Table 5-21a**, the mean PCME value for summer (0.0.00034 s/cc) was observed to be higher than the mean value for fall (0.000053 s/cc). The low levels of LAA detected in ambient air are presumed to be due to wind or other disturbances that released fibers from existing sources (soil, tailings, waste rock, outcrops, etc.) into air at the time of sampling.

The mean wind speed recorded at the OU3 Study Area meteorological monitoring station between 2007 and 2013 was 5.5 MPH, which is very similar to the mean wind speed measured during the ambient air sampling periods (5.0 MPH) during fall 2007 and summer and fall 2008. This illustrates that ambient air sampling was conducted during a period that closely represented typical wind conditions at the OU3 Study Area.

The *Final LAA HHRA* (EPA, 2015a) states that exposures to outdoor ambient air concentrations at the levels detected at the OU3 Study Area do not pose a significant risk to human health.

5.2.6.1 Summary of the Nature and Extent of LAA in Ambient Air

The data regarding LAA in ambient air are summarized below.

- PCME LAA levels in ambient air ranged from ND to 0.0056 s/cc.
- Ambient air sampling was conducted during a period that closely represented typical wind conditions at the OU3 Study Area.
- The *Final LAA HHRA* (EPA, 2015a) states that exposures to outdoor ambient air concentrations at the levels detected at the OU3 Study Area do not pose a significant risk to human health.

5.2.7 Activity-based Sampling (ABS) Air

Various investigations conducted within the OU3 Study Area have demonstrated that LAA is present in a variety of environmental media. However, the detection of LAA in a source medium, does not necessarily indicate that human exposures to LAA released to air during disturbances of these media would result in unacceptable exposures or risks (EPA, 2015a). The amount of LAA that could be released to air and inhaled depends on a number of factors, including the level of LAA in the source medium, the nature, intensity, and duration of the disturbance activity, meteorological conditions (e.g., relative humidity, wind direction, and speed), and conditions of the source medium (e.g., soil moisture content, vegetation coverage). Because of this, predicting the LAA levels in air based on measured LAA levels in source media is extremely difficult. For this reason, EPA recommends a source disturbance approach for investigating asbestos-contaminated Superfund sites (EPA, 2008g). This type of sampling is referred to as activity-based sampling (ABS) and involves the collection of personal air samples under "vigorous" source-disturbance conditions designed "to result in air concentrations that are at the high end of what could occur" (EPA, 2008g). The specific type and duration of disturbance activities used can be influenced by site-specific considerations. The air concentrations measured under these types of activities provide high-end estimates of potential inhalation exposure concentrations that can be used to calculate potential risks.

Personal air sampling was conducted as part of ABS events in the locations shown on **Figure 4-8**. ABS included collection of personal air samples during activities that were assumed to be consistent with possible activities that could occur in the OU3 Study Area. Air samples were analyzed for PCME LAA (samples collected during Phases III and IVA also included analysis for total LAA; these data are included in **Appendix E**, but are not discussed herein). During ABS, air monitors were worn by personnel that were engaged in a variety of source disturbance activities, and the resulting air filters were analyzed for LAA to determine the PCME LAA air concentration. These air concentrations were then used to estimate exposures for the purposes of evaluating potential human health risks (discussed in **Section 7.0**). It should be noted that personal air ABS concentrations varied considerably depending on the scenario, the intensity of the disturbance, location of the disturbance, level of LAA in the disturbed media, and meteorological conditions. Many of the ABS samples were indirectly prepared. As discussed previously (see **Section 3.5.1**), for the purposes of calculating EPCs for determining risk, an indirect preparation adjustment factor of 2.5 was used to account for the probable bias in air concentration estimates resulting from the use of an indirect preparation method. This same adjustment factor was utilized herein in order to allow a meaningful data summary to be presented.

Additional media were also collected in conjunction with several of the ABS events including ash, pre- and post-burn forest soil, tree bark, duff material, ambient air, and perimeter air samples. All ABS analytical data are provided in **Appendix E.**

The following sections present summaries of the ABS media results. Sample data are discussed herein in terms of ABS scenario and the distance from the center of the Former Mine Area, where the samples were collected:

- Near (within two miles from the center of the Former Mine Area),
- Intermediate (between two and six miles from the center of the Former Mine Area), and
- Far (greater than six miles from center of the Former Mine Area).

ABS data were utilized in the human health risk assessment, which is discussed in **Section 7.2**.

5.2.7.1 ABS Scenario – Recreational Hiking in the Forested Area

ABS air samples collected during this scenario were meant to simulate recreational visitor potential exposures while hiking in the forested area around the Former Mine Area (refer to **Section 4.8.1**). Samples were collected from near, intermediate, and far distances from the Former Mine Area Center and are summarized on **Tables 5-22a** and **5-22b**. Sample locations are presented on **Figure 4-8** and results are summarized below.

ABS Personal Air

- **Near:** A total of 12 ABS air samples were collected from ABS locations ABS-10 and ABS-14. The mean PCME LAA concentration for all Near hiking ABS air samples was 0.00050 s/cc.
- **Intermediate:** A total of 37 ABS air samples were collected from ABS locations ABS-03, ABS-05, ABS-06, ABS-07 and ABS-13. The mean PCME LAA concentration for all Intermediate hiking ABS air samples was 0.00065 s/cc.
- **Far:** A total of 26 ABS air samples were collected from ABS locations ABS-01, ABS-02, ABS-08, and ABS-11. The mean PCME LAA concentration for all Far hiking ABS air samples was 0.00023 s/cc.

For the Hiking scenario, LAA frequency of detections were highest in areas ABS-11 and ABS-14. The frequency of detection tended to be lowest in ABS areas located furthest from the mine. LAA was not detected in ABS samples in areas ABS-01, ABS-02, ABS-06, ABS-08, ABS-10, and ABS-13.

5.2.7.2 ABS Scenario – Lower Rainy Creek Hiking Including Antler Hunting

ABS air samples collected during this scenario were meant to simulate recreational visitor potential exposures while hiking (e.g., antler hunting) along LRC between Highway 37 and the Grace property line (refer to **Section 4.8.2**). Samples were collected from Intermediate distances from the Former Mine Area center and are summarized on **Tables 5-22a** and **5-22b**. The sampling location is presented on **Figure 4-8** (see area identified as "LRC Study Area") and results are summarized below in brief.

ABS Personal Air

- **Intermediate:** A total of 10 ABS air samples were collected along LRC with a mean PCME LAA concentration of 0.0093 s/cc.

5.2.7.3 ABS Scenario – Recreational ATV Riding in the Forested Area

ABS air samples collected during this scenario were meant to simulate recreational visitor potential exposures while riding ATVs in the forested area around the Former Mine Area (refer to **Section 4.8.1**). Samples were collected from near, intermediate, and far distances from the Former Mine Area Center and are summarized on **Tables 5-22a** and **5-22b**. Sample locations are presented on **Figure 4-8** and results are summarized below in brief.

ABS Personal Air

- **Near:** A total of 13 ABS air samples were collected from ABS locations ABS-10' and ABS-14. The mean PCME LAA concentration for all Near ATV ABS air samples was 0.0014 s/cc.

- **Intermediate:** A total of 36 ABS air samples were collected from ABS locations ABS-03, ABS-05, ABS-06, ABS-07, and ABS-13. The mean PCME LAA concentration for all Intermediate ATV ABS air samples was 0.00050 s/cc.
- **Far:** A total of 27 ABS air samples were collected from ABS locations ABS-01, ABS-02, ABS-08, and ABS-11. With the exception of ABS-11, which had one detected sample of 0.0060 s/cc, all ABS air samples were ND. The mean PCME LAA concentration for all Far ATV ABS air samples was 0.00022 s/cc.

For the recreational ATV riding scenario, LAA frequency of detection were highest in area ABS-10'. The frequency of detection tended to be lowest in ABS areas located furthest from the mine. LAA was not detected in ABS samples in areas ABS-01, ABS-02, ABS-05, ABS-06, ABS-08, ABS-13, and ABS-14.

5.2.7.4 ABS Scenario – Recreational Campfire Building

ABS air samples collected during this scenario were meant to simulate recreational visitor potential exposures while building campfires in the forested area around the Former Mine Area (refer to **Section 4.8.1**). Samples were collected from near, intermediate, and far distances from the Former Mine Area Center and are summarized on **Tables 5-22a** and **5-22b**. Sample locations are presented on **Figure 4-8** and results are summarized below in brief.

ABS Personal Air

- **Near:** A total of 10 ABS air samples were collected from ABS locations ABS-10' and ABS-14. The mean PCME LAA concentration for all Near Campfire Building ABS air samples was 0.0024 s/cc.
- **Intermediate:** A total of 40 ABS air samples were collected from ABS locations ABS-03, ABS-05, ABS-06, ABS-06', ABS-07, and ABS-13. The mean PCME LAA concentration for all Intermediate Campfire Building ABS air samples was 0.0022 s/cc.
- **Far:** A total of 26 ABS air samples were collected from ABS locations ABS-01, ABS-02, ABS-08, and ABS-11. The mean PCME LAA concentration for all Far Campfire Building ABS air samples was 0.00046 s/cc.

For the recreational campfire building scenario, LAA frequency of detection was highest in area ABS-10'. The frequency of detection was lowest in ABS areas located furthest from the mine. LAA was not detected in ABS samples in areas ABS-08, ABS-11, and ABS-14.

5.2.7.5 ABS Scenario – Residential Wood Harvester

ABS air samples collected during this scenario were meant to simulate potential exposures during non-commercial (e.g., residential) wood harvesting activities in the forested area in the OU3 Study Area (refer to **Section 4.8.2**). Scenarios included wood harvester driving, wood harvester cutting, felling and limbing, and cutting and stacking. Samples were collected from Intermediate and Far distances from the Former Mine Area center and are summarized on **Tables 5-22a** and **5-22b**. Although the study design was to perform ABS activities in ABS Area 10 (near), the location of the activities was modified at the time of collection to an area approximately one mile further downwind, closer to the Phase III ABS Area 6. Thus, to avoid potential confusion, the location of this area is referred to as ABS Area 6' (intermediate). Sample locations are presented on **Figure 4-8** and results are summarized below in brief.

ABS Personal Air

- **Intermediate**: A total of 60 ABS air samples were collected between the four different scenarios, listed above, from ABS locations ABS-06' and ABS-07. The mean PCME LAA concentration per scenario for these locations combined are 0.00013 s/cc (wood harvester driver), 0.0015 s/cc (wood harvester cutting), 0.0015 s/cc (felling and limbing), and 0.00070 s/cc (cutting and stacking). PCME LAA was detected in 14 of the 60 samples collected ranging in concentrations from ND to 0.0060 s/cc for the felling and limbing scenario in ABS-07.
- **Far:** A total of 32 ABS air samples were collected between the four different scenarios, listed above, from ABS location ABS-02 with a mean PCME LAA concentration per activity of 0 (wood harvester driver), 0.00025 s/cc (felling and limbing), and ND (cutting and stacking). The wood harvester cutting activity had less than three samples therefore a mean value was not calculated. PCME LAA was detected in only one of the 32 samples collected with a concentration of 0.0030 s/cc for the felling and limbing scenario in ABS-02.

For the residential wood harvester scenarios, LAA frequency of detection was highest in area ABS-06' for the cutting scenario. The frequency of detection tended to be lowest in ABS areas located furthest from the mine. LAA was not detected in ABS samples in areas ABS-06' (harvester felling and limbing and cutting and stacking scenarios), ABS-07 (harvester driving scenario), and ABS-02 (harvester driving, harvester cutting, and cutting and stacking scenarios).

5.2.7.6 ABS Scenario – USFS Worker Activities

ABS air samples collected during this scenario were meant to simulate potential exposures to USFS workers during activities routinely performed as part of the USFS land management responsibilities (refer to **Section 4.8.2**). Scenarios included trail maintenance, thinning trees, stand exam, cutting fire lines by hand, and cutting fire lines with heavy equipment. Samples were collected from intermediate and far distances from the Former Mine Area Center and are summarized on **Tables 5-22a** and **5-22b**. As noted above, although the study design was to perform ABS activities in area ABS Area 10 (near), the location of the activities was modified at the time of collection to be located about one mile further downwind, closer to the Phase III ABS Area 6. Thus, to avoid potential confusion, the location of this area is referred to as ABS Area 6' (intermediate). Sample locations are presented on **Figure 4-8** and results are summarized below in brief.

ABS Personal Air

- **Intermediate:** A total of 100 ABS air samples were collected between the five different scenarios, listed above, from ABS locations ABS-06' and ABS-07. The mean PCME LAA concentration per scenario for these locations combined are 0.00030 s/cc (trail maintenance), 0.00015 s/cc (thinning trees), 0.00051 s/cc (stand exam), 0.0069 s/cc (cutting fire lines by hand), and 0.0025 s/c (cutting fire lines with heavy equipment). PCME LAA was detected in 23 of the 100 samples collected ranging in concentrations from ND to 0.038 s/cc for the cutting fire lines by hand scenario in ABS-07.
- **Far:** A total of 50 ABS air samples were collected between the five different scenarios, listed above, from ABS location ABS-02 with a mean PCME LAA concentration per activity of 0.00030 s/cc (trail maintenance), 0.00030 s/cc (thinning trees), 0 (stand exam), 0.0045 s/cc (cutting fire lines by hand), and 0.0016 s/c (cutting fire lines with heavy equipment). PCME LAA was detected in 10 of the

50 samples collected ranging in concentrations from ND to 0.014 s/cc for the cutting fire lines with heavy equipment scenario in ABS-02.

For the USFS scenarios, LAA frequency of detection was highest in area ABS-07 for the cutting fire lines by hand scenario. The frequency of detection tended to be lowest in ABS areas located furthest from the mine. LAA was not detected in ABS samples in areas ABS-06' (worker trail maintenance, worker thinning trees, worker stand exam, cutting fire lines by hand scenarios) and ABS-02 (worker stand exam scenario).

5.2.7.7 ABS Scenario – Recreational Fishing

ABS air samples collected during this scenario were meant to simulate activities that might be performed by local river guides and recreational visitors and anglers on the sand bar (refer to **Section 4.8.3**). Samples were collected from a sand bar island in the Kootenai River immediately downstream of the confluence with Rainy Creek and are summarized on **Tables 5-22a** and **5-22b**. The sampling location is presented on **Figure 4-8** (see location identified as "Island") and results are summarized below in brief.

ABS Personal Air

- **Intermediate:** Two ABS air samples were collected on the sand bar; both samples were ND.

5.2.7.8 ABS Scenario – Commercial Logging

Unlike the ABS scenarios discussed above where only ABS air samples were collected, ABS air, tree bark, and duff material samples were collected and analyzed as part of the Commercial Logging ABS investigations. ABS air samples collected during this scenario were intended to simulate commercial logging activities in the forest proximate to the Former Mine Area (refer to **Sections 4.8.4 and 4.8.8**). Scenarios included site preparation, hand felling, hooking and skidding, mechanical processing, simulated milling/cutting slabs, and site restoration. Samples were collected from Near (in 2012) and Intermediate (in 2014) distances from the Former Mine Area Center, and are summarized on **Tables 5-19b** (tree bark), **5-20b** (duff), and **5-22a** and **5-22b** (ABS air). The 2012 samples collected from the Near distance were approximately 1.1 miles from the center of the Former Mine Area, whereas the 2014 samples collected from the Intermediate distance were approximately 4.5 miles from the center of the Former Mine Area. Sample locations are presented on **Figures 4-5a** and **4-8** and results are summarized below in brief by media type.

Tree Bark and Duff Material

- **Near:** Tree bark and duff material were collected from five near sample locations (CL-A through CL-E in which replicate analysis was performed three times on each sample, refer to **Figure 4-5a**). The highest tree bark surface loading levels and duff concentrations for LAA were from the trees collected from the near locations, with a mean PCME LAA concentration of 0.55 Ms/cm^2 and a mean total LAA concentration of 3.1 Ms/cm^2. The highest duff material concentrations for LAA also were from the duff material collected from the near locations, with a mean PCME LAA concentration of 100 Ms/g and a mean total LAA concentration of 384 MS/g. The maximum PCME LAA concentration for tree bark was 2.8 Ms/cm^2 collected from location CL-A and the maximum PCME LAA concentration for duff material was

194 Ms/g collected from location CL-B (refer to **Figure 4-5a**). These two locations are northeast of the Former Mine Area (i.e., in the prevailing wind direction), and are approximately 1.5 miles apart.

- **Intermediate:** Tree bark and duff material were collected from five intermediate sample locations (CL-F-1 through CL-F-5, refer to **Figure 4-5a**). Because fewer than three samples were collected for the tree bark and duff material Intermediate sample locations the mean was not calculated. Three of the five tree bark samples were ND, with the maximum PCME LAA surface loading level for tree bark of 0.054 Ms/cm^2 at CL-F-2. Four of the five duff material samples were ND, with the maximum PCME LAA concentration for duff material of 0.29 Ms/g at CL-F-5.

ABS Personal Air

- **Near:** A total of 13 ABS air samples were collected for the different scenarios, listed above, from the 2012 commercial logging ABS location with a mean PCME LAA concentration per activity of 0.0034 s/cc (hand felling) and 0.10 s/cc (skidding/hooking). All other activities had fewer than three samples, therefore, mean values were not calculated. Site preparation and cutting slabs ABS were not performed in the near location. PCME LAA was detected in all 13 of the samples collected ranging in concentrations from 0.00089 s/cc for the hand felling scenario to 0.16 s/cc for the skidding/hooking of timber scenario.
- **Intermediate:** A total of 29 ABS air samples were collected between the different scenarios, listed above, from the 2014 commercial logging ABS location with a mean PCME LAA concentration per activity of 0.0022 s/cc (hand felling) and 0.00065 s/cc (skidding/hooking). All ABS samples associated with cutting slabs pre-milling, mechanical processing, and milling were ND. The site restoration activity had fewer than three samples, therefore, a mean was not calculated. PCME LAA was detected in 3 of the 29 samples, ranging in concentrations from ND to 0.0079 s/cc for the site preparation scenario.

The commercial logging ABS near results indicate that the highest LAA air concentrations occur during scenarios that cause disturbances of duff and soil (e.g., skidding, bulldozing during site restoration activities), while scenarios that are associated mainly with disturbance of tree bark (e.g., sawing, processing, chipping) tend to produce lower LAA air concentrations. The ABS results also show the mean ABS air concentrations measured during the 2014 commercial logging investigation conducted in the Intermediate location are consistently lower than concentrations measured during the commercial logging investigation conducted in the Near location. In particular, air concentrations during skidding/hooking activities (which were the logging activities that resulted in the highest LAA releases in 2012) were more than 100 times lower in the 2014 investigation. This finding also is consistent with the results of the tree bark and duff materials sampled for the commercial logging scenarios in the near and intermediate locations, where the PCME LAA concentrations of both the tree bark and duff material were significantly lower the Intermediate locations than in the Near locations.

5.2.7.9 ABS Scenario – Wood-burning Stove Ash

ABS air samples collected during this scenario were meant to simulate a person emptying ash from a wood burning stove (refer to **Section 4.8.5**). ABS air, perimeter air, tree bark, and ash samples were collected and analyzed as part of this ABS investigation. Tree bark and ash samples were collected prior to the stove-emptying activity to provide information on LAA concentrations in materials selected for the burn. Perimeter air monitoring also was conducted during the wood burning and stove emptying events to verify that ABS activities did not result in

releases to air outside of the ABS area. Firewood was collected from dead trees at three locations at varying distances from the Former Mine Area: Near Mine (approximately one mile downwind of the Former Mine Area), Near Flower Creek (approximately two miles south of Libby and nine miles from the Former Mine Area), and Near Bear Creek (approximately 10 miles south of Libby and outside the current NPL boundary). Samples are summarized on **Tables 5-19b** (tree bark), **5-22a** and **5-22-b** (ABS air), **5-23** (ash), **5-25a** and **5-25b** (perimeter air). Firewood tree collection locations and maximum LAA detections for tree bark and ash are presented on **Figures 4-5b, 5-9c,** and **5-11**, respectively. The results are summarized below in brief by media type.

Tree Bark and Ash

- **Near Mine:** The highest tree bark surface loading levels for LAA were for the trees collected from the Near Mine location (WA-Near in which replicate analysis was performed three times on each sample), with a mean PCME LAA concentration of 0.92 Ms/cm^2 and a mean total LAA surface loading concentration of 6.1 Ms/cm^2. For ash samples (WA-Near in which replicate analysis was performed three times on each sample), the highest LAA concentrations were measured in ash following the burning of trees collected from the near location, with a mean PCME LAA concentration of 15 Ms/g and a total LAA surface loading concentration of 35 Ms/g.
- **Near Flower Creek**: The tree bark mean surface loading PCME LAA concentration for the Flower Creek location (WA-FC in which replicate analysis was performed three times on each sample) was 0.013 Ms/cm^2, and the mean total LAA concentration was 0.076 Ms/cm^2. The mean PCME LAA concentration in ash was 0 Ms/g and the total LAA concentration was 0.67 Ms/g (WA-FC in which replicate analysis was performed three times on each sample).
- **Near Bear Creek:** The tree bark mean surface loading PCME LAA concentration for the Bear Creek location (WA-BC in which replicate analysis was performed three times on each sample) was 0.0036 Ms/cm^2, and the mean total LAA concentration was 0.0088 Ms/cm^2. The mean PCME and total LAA concentrations in ash were both 1.8 Ms/g (WA-BC in which replicate analysis was performed three times on each sample).

PCME LAA and Total LAA mean levels for tree bark decreased as a function of distance from the Former Mine Area. These data also show that a significant amount of LAA remains in the ash after burning wood. This observation is consistent with trial burn experiments in woodstoves (Ward *et al.,* 2009) and in test burn chambers (EPA, 2012i), which indicated that the majority of LAA structures were retained in the ash when either wood or duff materials were burned under experimental conditions.

Perimeter Air

- A total of six perimeter air samples (three during the burn, and three during ABS) were collected to verify that ABS activities did not result in releases to air outside of the ABS area. All six perimeter air samples were ND for total LAA s/cc, refer to **Figure 5-12**.

ABS Personal Air The investigation consisted of three ABS events, where each event utilized firewood from the Near Mine, Near Flower Creek, and Near Bear Creek locations described above.

- **Near Mine:** The highest PCME LAA air concentrations in ABS air were for activities performed during the collection of ash generated from the burning of trees collected from the near location, with a mean ABS air concentration of 0.14 s/cc.

- **Near Flower Creek:** Mean PCME LAA air concentrations were 0.0074 s/cc for activities performed during the collection of ash generated from the burning of trees collected from the intermediate location.
- **Near Bear Creek:** Mean PCME LAA air concentrations were 0.0029 s/cc for activities performed during the collection of ash generated from the burning of trees collected from the far location.

The mean ABS air concentrations tended to decrease as a function of the tree collection distance from the mine. It should be noted that, a significant amount of variability in ABS air concentrations was noted between ABS events for each tree collection location (CDM Smith, 2013a). However, this variability was considered representative of the real variability that may be present in real exposure scenarios that may occur in Libby, and is not considered to be a data limitation (CDM Smith, 2013a).

5.2.7.10 ABS Scenario – Souse Gulch Campground Street Sweeper

ABS air samples collected during this scenario were meant to simulate workers driving street sweepers and water trucks used to wet/dampen sand and debris prior to being picked/swept up by the street sweepers within the Souse Gulch Campgrounds (refer to **Sections 4.6.7** and **4.8.6**). The USACE collected and analyzed ABS air, tree bark, and duff material samples as part of this ABS investigation. Tree bark and duff material were collected and analyzed for LAA to establish potential exposure to workers cutting down trees and disturbing duff material within the areas of the proposed Souse Gulch Campground renovations. Samples were collected from the Souse Gulch Campground area, which is an intermediate location from the Former Mine Area Center. Results are summarized on **Tables 5-19b** (tree bark), **5-20b** (duff), **5-22a** and **5-22b** (ABS air)**.** Sample locations are presented on **Figures 4-5a** and **4-8** and results are summarized below in brief by media type.

Tree Bark and Duff Material

- **Intermediate:** Tree bark and duff material were collected from sample locations within the Souse Gulch area (SG-DB stations; refer to **Figure 4-5a**). Because fewer than three samples were collected for the tree bark and duff material, the mean was not calculated. The maximum PCME LAA concentration for tree bark was 0.037 Ms/cm^2 at SG-DB7 and the maximum total LAA concentration was 0.20 Ms/cm^2 at SG-DB6. The maximum PCME LAA concentration for duff material was 5.7 Ms/g at SG-DB6 and the maximum total LAA concentration was 8.9 Ms/cm^2 at SG-DB7. The minimum PCME LAA concentration for tree bark and duff were both ND.

ABS Personal Air

- **Intermediate:** Five ABS air samples were collected from the Souse Gulch ABS locations during the street sweeping scenarios, no PCME LAA was detected during the Bobcat and Tennant equipment usage and the mean PCME LAA concentration was 0.00051 s/cc for the Tymco Regenrat equipment usage. Of the five ABS air samples collected, four were ND. The maximum PCME LAA concentration was 0.0015 s/cc.

5.2.7.11 ABS Scenario – Souse Gulch Wildfire

Opportunistic samples were collected during a natural wildfire, referred to as the Souse Gulch Wildfire, that occurred in the OU3 Study Area. ABS air, perimeter air, and ash samples were collected and analyzed as part of this investigation. ABS air samples were near firefighters fighting a natural fire and in the cockpit of the responding helicopter (refer to Section **4.8.7**). Opportunistic perimeter air samples were collected, including stationary monitors in the McGillivray Campground and a mobile station placed downwind of the fire and near responding ground-based firefighters. Ash samples were collected and analyzed to measure LAA concentrations in ash in the Souse Gulch burn area following the wildfire to provide information on the potential for subsequent exposures to human or ecological receptors. Samples were collected from the Souse Gulch and McGillivray Campground areas, which are intermediate locations from the Former Mine Area Center. Results are summarized on **Tables 5-21a** and **5-21b** (ambient air), **5-22a** and **5-22b** (ABS air), and **5-23** (ash). Sample locations are presented on **Figures 4-5a** and **4-8** and results are summarized below in brief by media type.

Perimeter Air

- **Intermediate:** Ambient air monitoring was conducted at one fixed station within the McGillivray Campground area (refer to **Figure 4-8;** location F-1) and at one mobile station. PCME LAA concentrations for both the fixed and mobile ambient air station samples were ND.

Ash

- **Intermediate:** Mean PCME LAA concentrations were observed in ash samples ranging from 15 Ms/g (Souse Gulch 1) to 26 Ms/g (Souse Gulch 2) with PCME LAA concentrations ranging from ND to 34 Ms/g. Mean Total LAA concentrations ranged from 51 Ms/g (Souse Gulch 1) to 75 Ms/g (Souse Gulch 2) with Total LAA concentrations ranging from 34 Ms/g to 90 Ms/g.

ABS Personal Air

- **Intermediate:** ABS air samples were collected during two different ABS scenarios; aircraft cockpit monitoring and firefighter ABS (refer to **Section 4.8.7**). The PCME LAA concentration result for the air craft cockpit monitoring was ND. For the firefighter ABS scenario, 15 samples were collected and the mean PCME LAA concentration was 0.00031 s/cc. Of the 15 firefighter ABS air samples collected, 13 were ND, with a maximum PCME LAA concentration of 0.0031 s/cc.

5.2.7.12 ABS Scenario – Nature and Extent Fire Line

ABS air samples collected during this scenario were meant to simulate firefighters cutting a fire line in the forested areas along the NPL boundary outside of the OU3 Study Area (refer to **Section 4.8.9**). Samples were collected from far distances from the Former Mine Area Center and are summarized on **Tables 5-22a** and **5-22b**. Sample locations are presented on **Figure 4-9** and results are summarized below in brief.

ABS Personal Air

- **Far:** A total of 60 ABS air samples were collected from 10 different ABS locations (2, 6, 19, 20, 22, 25, 32, 35, 40, and 46). PCME LAA was detected in seven of the 60 samples, ranging in concentrations from ND to 0.0023 s/cc in location 46. The overall mean PCME LAA concentration was 0.00017 s/cc.

No apparent spatial trends in these ABS concentration results were noted (CDM Smith, 2016). However, mean PCME LAA concentrations for these areas outside the NPL boundary were much lower than concentrations measured during similar ABS scenarios within the OU3 Study Area (see **Section 5.2.7.6**).

5.2.7.13 ABS Scenario – Slash Pile Burn

ABS air samples collected during this scenario were meant to simulate a forest worker creating a slash pile and then burning the slash pile (refer to **Section 4.8.10**). ABS air, tree bark, duff material, forest soil (pre- and post-burn), ash, and perimeter air samples were collected and analyzed as part of this ABS investigation. Prior to the burn, tree bark, duff material, and forest soil samples were collected to represent the materials included in the slash pile. One ash sample was collected from the burn area prior to conducting mop-up ABS activities for use in decision-making on potential mitigation measures in burn areas following a burn and soil samples were collected after the burn. Perimeter air samples were collected before, during, and after the burn to measure LAA concentrations in air at varying distances in close proximity to the burn area to provide information on the potential for offsite migration of LAA. Samples were collected from a near distance location from the Former Mine Area Center and are summarized on **Tables 5-12b** (pre-burn soil), **5-19b** (tree bark), **5-20b** (duff), **5-22a** and **5-22b** (ABS air), **5-23** (ash), **5-24** (post-burn soil), **5-25a** and **5-25b** (perimeter air). Sample locations are presented on **Figures 4-5a, 4-7b,** and **4-8**. Results are summarized below in brief by media type.

Tree Bark

- **Near:** Because fewer than three samples were collected for each of the tree bark sample locations the mean was not calculated. Three tree bark samples (SP15-TBark1, SP15-TBark2, and SP15-TBark3) were collected with PCME LAA concentrations ranging from 0.19 Ms/cm^2 to 0.78 Ms/cm2 and total LAA concentrations ranged from 1.9 to 5.5 Ms/cm^2.

Duff Material

- **Near:** Because fewer than three samples were collected for each of the duff material sample locations the mean was not calculated. Five duff material samples (SP15-Duff1 through SP15-Duff5) were collected with PCME LAA concentrations ranging from ND to 62 Ms/g and total LAA concentrations ranging from 12 Ms/g to 269 Ms/g.

Soil

- **Near**: Soil was collected pre-burn and post-burn and LAA was detected in all soil samples, with soil concentrations of Bin B1 (trace; <0.2%) to Bin B2 (<1%) in the fine ground fraction by PLM-VE. Trace levels of LAA also were present in the coarse fraction of all samples by PLM-Grav.

Ash

- **Near:** Ash sample mean PCME LAA concentrations were 482 Ms/g and mean total LAA concentrations were 2,555 Ms/g (sample IDs SP15-Ash1 through SP15-Ash3). The minimum PCME LAA concentration was 69 Ms/g and the maximum PCME LAA concentration was 698 Ms/g. The minimum total LAA concentration was 1729 Ms/g and the maximum total LAA concentration was 3392 Ms/g.

Perimeter Air

- **Near**: A total of 88 perimeter air samples were collected, 44 of which were analyzed for LAA. All of the pre-burn perimeter air samples were ND. During the burn, the LAA air concentrations tended to decrease with increasing distance from the burn area, with maximum PCME LAA concentrations ranging from 0.071 s/cc (at the west 50-foot monitor) to 0.0038 s/cc (at the west 200-foot monitor) . LAA was detected in only one of the post-burn perimeter air samples collected during the first day of post-burn monitoring (0.0038 s/cc at the north 50-foot monitor); all samples collected during the second day of post-burn monitoring were ND.

ABS Personal Air

- **Near:** A total of 36 air samples were collected, 18 of which were analyzed for LAA. LAA was detected in all of the personal ABS air samples collected during the slash pile construction and during dry and wet mop-up activities. In addition, with the exception of 2 samples, LAA was also detected in all of the personal ABS air samples collected during the slash pile burn. Mean PCME LAA concentrations ranged from 0.011 s/cc (during the burn activity) to 0.068 s/cc (during the wet mop-up activity). Because fewer than three samples were collected for the dry mop-up and the pile construction activities the mean values were not calculated. PCME LAA concentrations were highest during the dry mop-up activity (maximum PCME LAA concentration of 0.17 s/cc) and during the slash pile construction activity (maximum PCME LAA concentration of 0.19 s/cc) and lowest during the burn (maximum PCME LAA concentration of 0.028 s/cc).

5.2.7.14 ABS Scenario – Low-Intensity Prescribed Understory Burn

ABS air samples collected during this scenario were meant to simulate activities associated with a low-intensity prescribed understory burn (refer to **Section 4.8.11**). ABS air, tree bark, duff material, forest soil (pre- and post-burn), ash, and perimeter samples were collected and analyzed as part of this ABS investigation. Prior to the burn, tree bark, duff material, and forest soil samples were collected to represent the materials burned. One ash sample was collected from the burn area prior to conducting mop-up ABS activities for use in decision-making on potential mitigation measures in burn areas following a burn and soil samples were collected after the burn. Perimeter air samples were collected before, during, and after the burn to measure LAA concentrations in air at varying distances in close proximity to the burn area to provide information on the potential for offsite migration of LAA. Samples were collected from a near distance location from the Former Mine Area Center and are summarized on **Tables 5-12b** (pre-burn soil), **5-19b** (tree bark), **5-20b** (duff), **5-22a** and **5-22b** (ABS air), **5-23** (ash), **5-24** (post-burn soil), **5-25a** and **5-25b** (perimeter air). Sample locations are presented on **Figures 4-5a, 4-7b,** and **4-8**. Results are summarized below in brief by media type.

Tree Bark

- **Near:** Because fewer than three samples were collected for each of the tree bark sample locations the mean was not calculated. Four tree bark samples (B15-B1-T1 through B15-B4-T1) were collected with three PCME LAA concentrations of ND and one of 0.066 Ms/cm^2 surface loading. Total LAA concentrations ranged from ND to 0.67 Ms/cm^2 surface loading. The PCME LAA results were lower than those measured during the Slash Pile Burn Investigation.

Duff Material

- **Near:** Because fewer than three samples were collected for each of the duff material sample locations the mean was not calculated. Five duff material samples (B15-Duff1 through B15-Duff5) were collected with PCME LAA concentrations ranging from ND to 48 Ms/g and total LAA concentrations ranging from 5.7 Ms/g to 135 Ms/g. The PCME LAA results were lower than those measured during the Slash Pile Burn Investigation.

Soil

- **Near:** Soil was collected for both pre-burn and post-burn and LAA was detected in all soil samples, with all soil concentrations of Bin B1 (trace; <0.2%) in the fine ground fraction by PLM-VE. No samples had a coarse fraction of PLM-Grav.

Ash

- **Near:** The ash sample mean PCME LAA concentration is 179 Ms/g and mean total LAA concentration is 807 Ms/g (sample IDs B15-Ash1 through B15-Ash3). The minimum PCME LAA concentration was 54 Ms/g and the maximum PCME LAA concentration was 418 Ms/g. The minimum total LAA concentration was 362 Ms/g and the maximum total LAA concentration was 724 Ms/g. Results were lower than those measured during the Slash Pile Burn Investigation.

Perimeter Air

- **Near:** A total of 60 perimeter air samples were collected. All of the pre-burn perimeter air samples were ND. During the burn, the LAA air maximum PCME LAA concentrations ranged from 0.0039 s/cc (at the north 50-foot monitor) to 0.0058 s/cc (at the north 100-foot monitor) and 0.0039 s/cc (at the north 200-foot monitor). LAA was detected in only one of the post-burn perimeter air samples collected during the second day of post-burn monitoring (0.0019 s/cc at the north 50-foot monitor); all other post-burn samples were ND.

ABS Personal Air

Near: A total of 32 air samples were collected, 16 of which were analyzed for LAA. LAA was detected in all of the personal ABS air samples collected during the understory burn scenario activities. Mean PCME LAA concentrations were 0.078 s/cc (during the burn activity), 0.75 s/cc (during the dry mop-up activity), and 0.18 s/cc (during the wet mop-up activity). PCME LAA concentrations were highest during the dry mop-up activity and lowest during the burn. The dry mop-up activity yielded air concentrations that were approximately four times higher than the wet mop-up activity.

5.2.7.15 ABS Scenario – Mine Site Trespasser

ABS air samples collected during this scenario were meant to simulate potential exposures to trespassers who may enter the Former Mine Area (refer to **Section 4.8.12**). Scenarios included on- and off-road ATV riding, and rock hounding. Samples were collected from only near distances from the Former Mine Area Center and are summarized on **Tables 5-22a** and **22b**. Sample locations are presented on **Figure 4-8** and results are summarized below in brief.

ABS Personal Air

- **Near:** A total of 18 ABS air samples were collected during the rock hounding scenario with a mean PCME LAA concentration of 0.14 s/cc. PCME LAA was detected in 18 of the 18 samples collected during the rock hounding scenario, ranging in concentrations from 0.008 s/cc to 0.32 s/cc. A total of 18 ABS air samples were collected during the off-road ATV scenario with a mean PCME LAA concentration of 0.022 s/cc. PCME LAA was detected in 15 of the 18 samples collected during the off road ATV scenario ranging in concentrations from ND to 0.066 s/cc. A total of 24 ABS air samples were collected during the on road ATV scenario, from three different routes (A, B, and C), with a mean PCME LAA concentration of 0.0030 s/cc, 0.0024 s/cc, and 0.022 s/cc, respectively. PCME LAA was detected in 12 of the 24 samples collected during the off road ATV scenario ranging in concentrations from ND to 0.048 s/cc.

For the Mine Site Trespasser scenarios, LAA frequency of detection was 100% for the rock hound scenario. For the ATV riding scenarios the LAA frequency of detections was highest for the off-road riding vs. the on-road scenario. The frequency of detection for the on-road ATV scenario was highest along Route C.

5.2.7.16 Summary of ABS Results

Personal air ABS result concentrations span several orders of magnitude depending on the scenario, the intensity of the disturbance scenario, location of the disturbance, level of LAA in the disturbed media, and meteorological conditions. The personal air ABS concentrations tend to decrease with distance from the Former Mine Area, which is also consistent with the mean levels for both tree bark and duff material that also tend to decrease as a function of distance from the Former Mine Area. These ABS air data are used in the human health risk assessment (see **Section 7.2**) to evaluate potential exposures and risks from inhalation of LAA.

5.2.8 Tissues

Tissues. As discussed in **Section 4.14**, fillet samples for fish collected from the Mill Pond were analyzed for LAA by TEM. **Table 5-26** presents a summary of the fish tissue results; this table provides detailed information on each fish collected (species, length, weight), as well as the analysis results. Structure counts and tissue concentrations are presented based on both total LAA (all recorded structures) and LAA >10 µm, because this is the concentration metric that is used for the purposes of evaluating potential ingestion exposures. LAA was detected in each fish fillet sample and total LAA results ranged from 9.4E+03 to 6.4E+06 structures per gram of tissue on a wet weight basis (s/g, ww), with a mean concentration of 1.2E+06 s/g, ww. The mean concentration based on LAA >10 µm was 4.2E+04 s/g, ww.

Tissue samples from a mule deer hunted near the Former Mine Area also were analyzed for LAA by TEM. Tissue samples included inside shoulder and backstrap muscle samples (for assessing potential human health risks associated with the ingestion of LAA in game tissue) and other target organs, including the heart, liver, lung, kidney, and diaphragm. LAA was not observed in any deer tissue sample (refer to **Table 5-26**).

5.2.8.1 Summary of the Nature and Extent of LAA in Tissues

LAA fibers were present in the fillet tissues of fish collected from the Mill Pond, but LAA was not detected in any muscle or organ tissues of a mule deer that was hunted from within the OU3 Study Area.

6 CONTAMINANT FATE AND TRANSPORT

This section describes the processes affecting the fate and transport of LAA and non-asbestos constituents in the OU3 Study Area. The evaluation of LAA and non-asbestos constituent fate and transport is based on the OU3 Study Area physical characteristics, source characteristics, and the results of the LAA RI sampling investigations. Separate fate and transport discussions are presented below for LAA and non-asbestos constituents because there are fate and transport characteristics that are unique to each.

6.1 Fate and Transport of LAA

6.1.1 Source and Mechanism for Release

LAA occurs naturally in the environment and may be released to water and air from erosion and the weathering of natural deposits of LAA-bearing rocks. LAA also may be released to the environment when these natural deposits are disturbed, such as during mining operations. Asbestos is released to the environment from the crushing, screening, and milling of ore, the processing of asbestos products, the use of asbestos-containing materials, and the transport and disposal of asbestos-containing materials (ATSDR, 2001a). In the OU3 Study Area, historical mining, milling, and processing of vermiculite at the Former Mine Area, between 1920 and 1990, caused releases of LAA to the environment. Erosion of the exposed source rock, waste rock piles, and tailings also caused releases to the environment. Although the primary mechanism for release of LAA is no longer occurring (i.e., the crushing, screening, and milling of ore), varying levels of LAA remain in tailings, waste rock, and naturally occurring material (e.g., LAA-bearing glacial till).

6.1.2 Fate and Transport Mechanisms

Once asbestos fibers enter the environment, they tend to settle out of the air or water and deposit onto soil and sediment (EPA, 1979; Millette, 1979). The following subsections further address fate and transport mechanisms in these media at the OU3 Study Area.

6.1.2.1 Air

Once LAA fibers are released, the primary transport mechanism for fibers is by air, fibers will then be deposited to other locations and possibly onto other media (e.g., soil, water, tree bark, duff material). The rate at which asbestos particles are deposited likely depends on their size and aerodynamic characteristics. Jaenicke (1980) reported that submicron particles are removed rapidly "because of their large mechanical mobility and their attachment to larger aerosol particles." At the other end of the spectrum, the largest particles (~100 µm in diameter) are "removed quickly (in hours) because of the large sedimentation rate." Particles of intermediate size, ranging from 0.1 microns to several microns in radius exhibit the largest residence time. These are generic observations for generic particles, and the aerodynamics of LAA were not evaluated in this report.

Air transport of LAA near the Former Mine Area likely occurred during the active mining, milling, and processing activities, especially during the period when dry processing was performed (prior to 1974, see **Section 1.3**). After mining activities ceased (i.e., since 1990), it is possible that some suspension of LAA occurred during significant wind events, or ground-disturbing activities in the OU3 Study Area. The potential for suspension of LAA is greatest in the mining disturbed

area where source rock, mined materials, and tailings are exposed at, or near, the ground surface. However, based on ambient air monitoring conducted in these areas, LAA levels detected were not high enough to demonstrate significant LAA transport at levels that pose a significant human health risk.

It is possible that air can also transport LAA fibers that are present in LAA-impacted bark or duff when it burns, either during a forest fire or during burning of LAA-impacted bark in a fireplace or woodstove (see **Section 6.1.2.5**). However, as demonstrated during perimeter air monitoring during understory and slash pile burn ABS tests, LAA levels detected in smoke during these events were not high enough to pose a significant human health risk. It is also likely that fibers detected in air during these events were due to mechanical and other direct human disturbance of ash, rather than released in smoke during the burning of trees and duff. As further described in **Section 6.1.2.6** below, in burn chamber studies conducted by EPA (EPA, 2012i), the majority of LAA fibers that are present in duff when burned were shown to remain in ash and did not become entrained in air emissions.

The RI sampling results indicate that the areas with the relatively highest concentrations of LAA in the soil, tree bark, and duff away from the mined area generally are present within a northeast/southwest-trending area that correlates with the prevailing wind directions. This is demonstrated by the LAA impacted areas shown on **Figure 5-9a** and **5-9b**.

Additionally, an air dispersion and deposition model was created by Reax Engineering to be used in conjunction with collected sample data. The model was created using EPA's American Meteorological Society/EPA Regulatory Model (AERMOD) modeling system. The model report is included in **Appendix J**. The model was based on the previously conducted air dispersion modeling that CDM Smith performed for the site on behalf of EPA.

The Reax/Grace model was run initially without deposition to confirm that the model results were comparable with the EPA/CDM model. The Reax/Grace AERMOD analysis was found to be a more conservative model as discussed in the report. Observed differences are likely related to the differences in the weather data utilized.

The Reax/Grace model includes the use of a particle size distribution drawn from available historical data (references listed in the modeling report) allowing for particulate deposition to be enabled. This approach may more accurately reflect real conditions because it includes particulate deposition. Modeled deposition rates are provided only to illustrate the extent of potential historical deposition rates and are not indicative of current exposures or risks. The model output data are presented on **Figure 6-1**. As shown on **Figure 6-1**, the highest deposition rates are predicted near the Former Mine Area.

6.1.2.2 Water and Sediment

It is possible that LAA fibers may enter water bodies via air or erosion of soils, mine waste material, and sediments that contain LAA, or through contact with natural, LAA-bearing materials (e.g., bedrock outcrops or glacial material). In water, the distance that LAA fibers may travel from the point of origin likely depends on the surface chemistry and mineralogy of the fiber (EPA, 1979), and the flow rate.

After eroded LAA-bearing soils enter the water, LAA fibers may remain suspended in the water column even after soil particles have settled. However, Libby Site data suggest that LAA concentrations in water tend to increase when the level of turbidity increases (CDM Smith, 2014a).

This is consistent with published findings that indicate that asbestos concentrations were highest in water when turbidity levels were above approximately 0.2 NTUs (Logsdon, 1979). However, fiber interaction with natural organic matter may increase precipitation (ATSDR, 2001a; EPA, 1979). Studies have shown that asbestos fibers in water will adhere to algae, perhaps due to the positive surface charge of the fibers, which results in clumping and increased settling (Webber and Covey, 1991). Because there may be a range of asbestos fiber sizes in water, and settling time differs by size, there may be a vertical distribution of asbestos fibers in large bodies of water (Chatfield and Dillon, 1983). Even after settling, asbestos fibers in sediment may be re-entrained into water following sediment disturbances.

In the OU3 Study Area, surface runoff (and associated eroded materials) generally drains from the mine areas to the Fleetwood Creek and Carney Creek basins. LAA fibers entrained in these creek flows largely settle out in the streambed sediments, overbank deposits, or in the sediments in the impoundments along the drainage path (see **Section 5.2.4**). As discussed in **Section 5.2.4**, concentrations of LAA ranged widely in surface water samples collected in Fleetwood Creek, Carney Creek, LRC, and the Kootenai River (refer to **Figure 5-4a**). Other studies have shown that asbestos concentrations in surface water near natural chrysotile deposits in California are usually highest during or after rain events (Webber and Covey, 1991). At the Libby Site, surface water monitoring of streams near the mine show similar results; LAA concentrations in water tend to vary seasonally, with the highest concentrations reported in the spring during periods of runoff (CDM Smith, 2016). During periods of high flow (when LAA concentrations are generally highest in surface water), LAA fibers likely settle out in overbank deposits away from the main stream channel, or across the banks and shorelines of impoundments.

6.1.2.3 Groundwater

It has been demonstrated that entrainment of LAA in water is typically correlated with higher flow velocity. Given the low seepage velocity and natural filtration that typically occurs in porous aquifers, it is expected that very little transport of LAA would occur within groundwater. The general lack of significant LAA levels detected in groundwater samples collected over time supports this conclusion.

6.1.2.4 Soil

Movement of LAA fibers through soils or from soil to surface water occurs during surface runoff or erosion. Asbestos fibers in soil are fairly immobile, and fibers less than 2 µm in diameter will tend to move at the same rate as clays (EPA, 1979). LAA fibers in soil can become suspended in the air by activities that disturb the LAA entrained in soil. The release of LAA from soil to air depends upon many factors, including the soil moisture content (drier conditions tend to increase release), vegetation coverage and condition (plant cover will tend to decrease release), and the intensity of the disturbance activity (higher intensity activities will result in higher releases).

As discussed in **Section 5.2.2**, the highest concentrations of LAA in the OU3 Study Area soil samples were generally measured in samples collected near the mine area (samples collected from a road on one of the mine benches and waste rock samples contained the highest levels of LAA by PLM-VE). The LAA in the soil has the potential to be suspended in air or water if the soil is disturbed by an activity, or transported via runoff/erosion (refer to **Figure 5-1a**).

6.1.2.5 Tree Bark and Duff Material

Studies suggest that LAA fibers may also settle onto the ground surface and the outer surface of trees (bark) (Ward *et al.,* 2006 and 2012). Data on LAA levels on the bark surface of trees have been collected in the forested area near the Former Mine Area and within approximately one to two miles away from the NPL boundary. These data showed that tree bark surface loading levels of LAA tended to be relatively highest on trees collected closest to the mine, northeast of the mine center in the direction of prevailing winds, and southwest of the mine center along Rainy Creek (refer to **Figures 5-9a** through **5-9c**).

LAA fibers on the tree bark or in the duff can be lofted into the air during commercial logging or wood-gathering activities. When trees die or otherwise exfoliate the outer layers of bark, the bark is transferred to the forest floor. The LAA fibers on the bark of a dead tree or exfoliated bark from a living tree will become a component of the forest duff material, and will eventually be combined with the soil. For example, research conducted at the University of Montana on ponderosa pines within the southeastern Klamath Mountains found 34 to 49 percent of material within the upper layers of duff mounds beneath the trees consisted of sloughed bark (Garlough, 2010). Ponderosa pines are found in warmer, dryer areas of the OU3 Study Area; therefore, it can be assumed that similar amounts of sloughed bark contribute to the upper layer of duff materials in these areas. Like soil, the LAA in the duff material has the potential to mobilize if the duff material is disturbed by an activity or transported via runoff/erosion.

Bark sloughing or exfoliation is a widely observed phenomenon in woody plants and occurs as an active physiological process as well as a mechanical weathering process (Chang, 1954, Esau, 1965; Kramer and Kozlowski, 1960 and 1979; Addicott, 1982). Trees that germinated after mining activities ceased are expected to have significantly less LAA in bark. LAA on the bark of older trees is likely to diminish naturally, as the bark exfoliates and becomes entrained into the duff mound at the base of the tree. Similarly, the concentration of LAA in the materials contributing to the duff volume (e.g., exfoliated bark, falling branches, stems, leaves, needles, pine cones) is also likely to diminish naturally over time. Eventually, LAA fibers in the duff material are expected to be buried by un-impacted duff material, which will then decompose, thereby reducing the overall LAA concentrations in soil. The rates at which duff generation and decomposition occur are currently unknown for the OU3 Study Area, and have not been widely studied for a similar ecosystem; therefore, the rates of natural reduction of LAA in bark and duff cannot yet be predicted. Recently-collected bark and duff samples suggests this process occurs very slowly, on the order of decades.

6.1.2.6 Ash and Smoke

Studies have shown that asbestos fibers can become entrained in ash following the burning of asbestos-contaminated wood and duff (EPA, 2012i; EPA, 2013d; Ward *et al.,* 2009). The results of these studies indicate that the majority of LAA fibers remained in the ash following the combustion process. For example, in the EPA study (EPA, 2012i), an average of 92% to 99% of the asbestos fibers remained in the residual ash after the test burns. These results also suggest that the potential for LAA to be mobilized in smoke is insignificant. Similarly, perimeter air monitoring during understory and slash pile burn ABS showed that LAA levels in smoke were well below levels that may pose a significant human health risk. It is unknown whether these results would be representative of conditions that would be encountered in a large fire.

Following the burning of LAA-impacted bark and duff, the resulting LAA-impacted ash has the potential to mobilize if the ash is disturbed (e.g., due to physical disturbance such as firefighter dry mop-up activities, precipitation or wind events, or via erosional processes).

The EPA and others have conducted additional studies to simulate forest fire combustion of LAA-impacted biomass (EPA, 2012k; EPA, 2013e; EPA, 2013f). These reports are summarized below.

- *EPA Technical Memorandum. Subject: Simulation of Forest Fire Combustion of Amphibole Contaminated Biomass with Resultant Health Risk Assessment for Residents of Libby, Montana (EPA, 2012k).* This technical memorandum summarizes data and analysis that estimates asbestos air concentrations that may occur as a result of a forest fire in the OU3 Study Area. Results from this report were based on results of the EPA, 2012a study. Two scenarios were used (simulation of smoldering and flaming conditions) in the trials, resulting in the development of human health cancer risks and cancer hazard estimates. The final conclusions state, "Whether fires occur at a frequency of one every 70 years or two fires every 70 years at the vermiculite mine site, both cancer risks and non-cancer hazards are found to be below EPA targets."
- *EPA Evaluation of Impacts of Forest Fires That Occur in Operable Unit 3 on Air and Soil in Libby (EPA, 2013e).* This memorandum describes studies and calculations performed by EPA to estimate potential LAA exposures to residents in Libby associated with forest fires in the OU3 Study Area. Results summarized from this memorandum state, "…EPA has determined that exposures and health risks to residents in Libby are likely to be low, both from direct inhalation of fibers in air and by deposition of fibers to soil."
- *EPA Evaluation of Exposure to Firefighters in Operable Unit 3 (EPA, 2013f).* This memorandum describes calculations performed by the EPA to estimate potential LAA exposures to firefighters in the OU3 Study Area. EPA concludes, "Estimated exposure of firefighters in OU3 to LAA in smoke might exceed the OSHA standard for short times under worst case or high-end conditions, but typical short term and long term exposures are likely to be within OSHA limits."
- *Detailed TEM Results for Air Samples Collected During the Souse Gulch Wildfire (CDM Smith, 2016).* On July 28, 2013, a small fire in the Souse Gulch day-use area on Lake Koocanusa burned approximately 1.5 acres. Air samples were collected during the fire, including firefighter activity-based sampling (ABS, n=16), a mobile monitor, which ran for approximately four hours, a Libby Airport helicopter (approximately one-hour sample), and from the McGillivray campground (approximately 24 hours). TEM results showed that only two of 16 ABS samples measured LAA, with results near the sensitivity levels of the analysis.

From a fate and transport perspective, the results of the above studies demonstrate that the transfer of LAA to smoke from LAA-impacted biomass is insignificant relative to other fate and transport mechanisms. Additional modeling, particularly for a large-scale event, will need to be evaluated to contribute to these conclusions.

6.1.3 Contaminant Persistence

Asbestos fibers are non-volatile and insoluble. They may be transported and distributed by air and water and tend to persist under typical environmental conditions (ATSDR, 2001a). There are differences in the ability of different types of asbestos to persist in the environment. For instance, ASTDR concluded that chrysotile asbestos may degrade more readily than amphibole asbestos

under certain environmental conditions (e.g., acidic environments) (ATSDR, 2001a). Possible transformation and degradation for each environmental medium is discussed below.

Air. ASTDR has concluded that asbestos particles are not known to undergo any significant transformation or degradation in air (ATSDR, 2001a).

Water. Asbestos fibers are relatively stable in water and are not prone to significant chemical or biological degradation. However, some asbestos fibers may undergo chemical alteration and adsorb additional organic agents. In general, asbestos does not volatilize from water surfaces. In water, at low pH, chrysotile asbestos may undergo some dissolution, as magnesium hydroxide leaches from the outer brucite layer, but amphibole asbestos is expected to persist in aquatic environments with little change for long periods of time (ATSDR, 2001a).

Soil. In general, asbestos fibers are not known to undergo significant transformation or degradation in soil (ATSDR, 2001a).

6.2 Fate and Transport of Non-asbestos Constituents

6.2.1 Source and Mechanism for Release

Non-asbestos constituents such as metals and metalloids occur naturally in the environment and are released during erosion and the weathering of natural deposits of metal/metalloid-bearing rocks. The rate that metals/metalloids are released to the environment may be accelerated when these natural deposits are disturbed, such as during mining operations. Water that contacts exposed hillsides, waste rock piles, and mine tailings has the potential to mobilize (by eroding or leaching) metals/metalloids. As a result, metals/metalloids can become concentrated in depositional areas (e.g., in sediments), or dissolved or suspended in surface water or groundwater at concentrations.

Some chemicals used at the mine in the processing of vermiculite ore might also be present in on-site waste materials. Various reagents were used to facilitate the separation of higher quality ores from lesser quality ores. The reagents reported included #2 Diesel fuel, Armeen T (tallow alkyl amine), fluorosilicic acid, and lesser quantities of flocculants, defoamers, frothers, and other reagents. In addition, past use of the application of oil on mine roads as a dust control measure was reported (EPA, 2007b).

6.2.2 Fate and Transport Mechanisms

6.2.2.1 Soil and Sediment Transport

Soil constituents may be physically transported through mass wasting and erosion. Mass wasting is a general term for "*the dislodgement and downslope transport of soil and rock material under the direct application of gravitational body stresses*" (Bates and Jackson, 1997). Evidence of mass wasting in the OU3 Study Area includes the slumping and downslope movement of the waste rock piles. Erosion is the "*general process or group of processes whereby the materials of the Earth's crust are loosened, dissolved, or worn away, and simultaneously moved for one place to another, by natural agencies, which included weathering, solution, corrasion*[7]*, and transportation*" (Bates and Jackson, 1997). The primary mechanism of erosion in the OU3 Study

[7] Corrasion is a process of erosion whereby rocks and soil are mechanically removed or worn away by the abrasive action of solid materials moved along by wind, waves, running water, glaciers, or gravity.

Area is erosion by water (e.g., water flowing in streams, and precipitation and snowmelt runoff). Conceptually, as runoff water flows over and off exposed hillsides, waste rock piles, and mine tailings, the soil and rock particles (and the associated inorganic and organic constituents) can be transported and deposited on the ground surface, and in surface water channels and ponds. Deposition is dependent on sediment size, flow velocities, and stream-channel morphology. It is unlikely that wind erosion has a major role in moving soil and rock in the OU3 Study Area.

6.2.2.2 Surface Water and Groundwater Transport

In addition to acting to physically erode and transport soil and sediments as described above, surface water can dissolve and leach constituents from the source rock. The constituents can remain dissolved in the surface water flow, or precipitate out in down gradient locations (e.g., along stream banks or in pond sediments). Infiltrating surface water also can transport constituents to groundwater. Dissolved or suspended constituents in groundwater can flow down gradient within the groundwater system, or can discharge back to surface water at seep locations. Water also can move through the subsurface as interflow, which is the lateral movement of water in the unsaturated zone that first returns to the surface or enters a stream prior to becoming groundwater. Interflow within waste rock and tailings has the potential to transport constituents (either dissolved or suspended) to down-gradient seep or stream locations.

6.2.3 Contaminant Persistence

Inorganic, non-asbestos constituents (metals and metalloids) generally do not decay or biodegrade and will persist through time. Natural processes cause attenuation of metals/metalloids as they are transported along pathways away from the source areas. These processes include precipitation, sorption, dilution, and dispersion. Organic, non-asbestos constituents are somewhat less persistent (compared to metals/metalloids) as they are also subject to volatilization and bio-transformations. Eventually, the organic, non-asbestos constituents degrade to compounds such as carbon dioxide and water.

7 RISK ASSESSMENTS FOR LAA AND NON-ASBESTOS CONSTITUENTS

The EPA has evaluated the risks posed by LAA and non-asbestos constituents separately and a summary of the risk assessments for LAA and non-asbestos constituents are presented below.

7.1 RISK ASSESSMENT OVERVIEW

7.1.1 LAA Risk Assessments

The EPA prepared an initial screening-level human health risk assessment for exposure to LAA at the OU3 Study Area in 2011 (EPA, 2011c). The initial risk assessment was considered a screening-level assessment because not all of the data used in the assessment had been validated at the time (i.e., RI data collected through 2010), and because the EPA was in the process of, but had not yet completed, developing LAA-specific cancer and non-cancer toxicity factors. The screening-level risk assessment provided initial estimates of the levels of risk that may be associated with LAA exposure during a range of different types of human activities in the OU3 Study Area. In December 2014, the EPA released the final LAA-specific cancer and non-cancer toxicity factors (detailed below in **Sections 7.2.1 and 7.2.2**), and EPA finalized the *LAA HHRA* in 2015.

The final risk assessments for LAA are included in the following documents:

- The Final Site-wide Human Health Risk Assessment (for LAA) (EPA, 2015a; referred to throughout this report as the *Final LAA HHRA*) was issued in November 2015. The purpose of this report was to quantify potential human health risks from exposures to LAA at the Libby Site under current and reasonably anticipated future use. This risk assessment is summarized below in **Section 7.2** and a copy of the complete report is provided in **Appendix K**.
- The Final Site-wide Baseline Ecological Risk Assessment (for LAA) (EPA, 2014a; referred to throughout this report as the *Final Asbestos BERA*) was issued in December 2014. The purpose of this report was to describe the likelihood, nature, and extent of adverse effects on ecological receptors in all of the Libby Superfund OUs, including the OU3 Study Area, that result from exposure to LAA released to the environment as a result of past mining, milling, and processing activities at the OU3 Study Area. This risk assessment is summarized below in **Section 7.3** and a copy of the complete report is provided in **Appendix K.**

7.1.2 Baseline Risk Assessments for Non-Asbestos Constituents

The final risk assessments for non-asbestos constituents are included in the following documents (note that non-asbestos risk assessments only were performed for the OU3 Study Area and not the entire Libby Site):

- Final Human Health Risk Assessment for Non-Asbestos Contaminants – Operable Unit 3 – Libby Asbestos Superfund Site - Libby, Montana (CDM Smith, 2013b; referred to throughout this report as the *Final Non-Asbestos HHRA*). The purpose of this report was to quantify potential human health risks from exposures to non-

asbestos COPCs at the OU3 Study Area under current and future conditions. This risk assessment is summarized below in **Section 7.4** and a copy of the complete report is provided in **Appendix K**.

- Final Baseline Ecological Risk Assessment for Non-Asbestos Contaminants - Operable Unit 3 – Libby Asbestos Superfund Site - Libby, Montana (CDM Smith, 2013b; referred to throughout this report as the *Final Non-Asbestos BERA*). The purpose of this report was to describe the likelihood, nature, and extent of adverse effects on ecological receptors in the OU3 Study Area that result from exposure to non-asbestos constituents released to the environment as a result of past mining, milling, and processing activities at the OU3 Study Area. This risk assessment is summarized below in **Section 7.5** and a copy of the complete report is provided in **Appendix K**.

7.1.3 General EPA Risk Assessment Methods

As a general policy, the EPA uses the results of the baseline risk assessments to determine whether a release or threatened release poses potential risks to human health or the environment (ecological receptors) that may warrant remedial action and to determine if a site presents an imminent and substantial endangerment (EPA, 1991). In addition, the results of the baseline risk assessments may be used in concert with other factors to determine the appropriate remedial response. Risk management decisions generally take into account the sum of all the risks contributed by differing exposure scenarios, rather than simply evaluating each one independently.

A HHRA presents estimates of both cancer risks and non-cancer hazards that may result from exposure to contaminants. Cancer risk is defined as the probability that cancer will occur as a result of incremental lifetime exposure to non-asbestos constituents occurring at the site. Compound-specific cancer risks are computed for individual carcinogenic constituents. Total or cumulative cancer risks are computed by summing the compound-specific cancer risks for a given receptor.

Non-cancer hazard is expressed as a Hazard Quotient (HQ), which is estimated as the ratio of the constituent exposure (dose) over a period of time to a reference dose (a dose not expected to be associated with any appreciable non-cancer health effect). Cumulative and/or multi-media constituent exposures at a site are evaluated by summing constituent HQs to estimate a Hazard Index (HI). Because non-cancer effects are organ specific, further refinement of the HI can be accomplished by deriving target-organ-specific HIs (i.e., summing HQs only for those constituents that have similar target organs).

Where the baseline risk assessment indicates that a cumulative site risk to a receptor using reasonable maximum exposure assumptions for either current or future land use exceeds a cancer risk of 1E-04 (one additional cancer in ten thousand exposed people), or if the HQ or HI exceeds 1.0, action under CERCLA is generally warranted. However, on a site-specific basis, the EPA may determine that remedial action is warranted when cumulative cancer risks are between the 1E-06 to 1E-04 range (EPA, 1991).

A BERA presents a “weight of evidence” evaluation to determine whether there is a likelihood of significant and ecologically relevant adverse effects (risk) posed to specific receptor group populations (e.g., fish, mammals, invertebrates, etc.) for site constituents of concern. The weight of evidence is determined for each receptor group by evaluating the results of various measures of effect (also known as lines of evidence) to determine whether the preponderance of the

evidence either supports or refutes a finding of risk. Lines of evidence typically include estimates of risk based on receptor-specific HQ values (Chemical-specific HQs for ecological receptors are typically computed by dividing a media concentration or potential receptor dose by its corresponding toxicity reference value (TRV)), and results of multiple empirical studies that address measures of effect on endpoints of concern; typically organism growth, survival or reproduction. These effect studies may be laboratory or field based.

For the *Final Asbestos BERA* for the OU3 Study Area, HQ values were not computed because ecological toxicity reference values for asbestos do not exist. Instead, the *Final Asbestos BERA* for the OU3 Study Area relies on site-specific field and laboratory empirical studies to support the weight of evidence analysis.

Summaries of the LAA and non-asbestos human health and ecological risk assessments follow in the remainder of this section.

7.2 LAA HUMAN HEALTH RISK ASSESSMENT

The purpose of the *Final LAA HHRA* document (EPA, 2015a) is to estimate potential human health risks from potential exposures to LAA at the Libby Site under current and foreseeable future conditions. The *Final LAA HHRA* is a comprehensive document for the entire Libby Site; therefore, there is not a separate HHRA for the OU3 Study Area. The *Final LAA HHRA* assessment is discussed in further detail below with citations from the *Final LAA HHRA* presented as quotations. The complete document is provided in **Appendix K.**

7.2.1 Toxicity Assessment

"The adverse effects of asbestos exposure in humans have been the subject of a large number of studies and publications. Exposure to asbestos may induce several types of both non-cancer and cancer effects. A detailed summary of the cancer and non-cancer effects of asbestos is provided in the ATSDR *Toxicological Profile for Asbestos* (ATSDR, 2001b) and in EPA's *Airborne Asbestos Health Assessment Update* (EPA, 1986). A detailed summary of effects related specifically to LAA is provided in the *Toxicological Review for Libby Amphibole Asbestos* (EPA, 2014b)" (EPA, 2015a).

7.2.1.1 Cancer Effects

"Many epidemiological studies have reported increased mortality from cancer in workers exposed to asbestos, especially from lung cancer and mesothelioma (tumor of the thin membrane that covers and protects the internal organs of the body). In addition, a number of studies suggest asbestos exposure may increase risk of cancer of the larynx (commonly called the voice box) and ovarian cancer (IARC, 2012). Based on these findings, and supported by extensive data from animal studies, EPA has classified asbestos as a known human carcinogen" (EPA, 2015a) via the inhalation exposure pathway on its Integrated Risk Information System (IRIS). IRIS is an electronic database containing human health toxicity values for various constituents.

"Cancer risk from inhalation exposure is determined based on an inhalation unit risk (IUR) value, which is defined as the excess lifetime cancer risk estimated to result from continuous exposure to one asbestos fiber per cubic centimeter of air (1 f/cc). The LAA-specific IUR, referred to as IUR_{LA}, is derived from a group of workers employed at the vermiculite mining and milling operation

in and around Libby, referred to as the "Libby worker cohort". The IUR_{LA} is 0.17 $(PCM\ f/cc)^{-1}$ (EPA, 2014b)." (EPA, 2015a)

Data on cancer risks from ingestion-only exposure are limited; however, the "EPA has determined that there is an increased risk of developing benign intestinal polyps as a consequence of long-term ingestion of asbestos-contaminated drinking water. This finding is the basis for the MCL for asbestos in drinking water (EPA, 2015a)." The MCL for asbestos in water is based on an oral slope factor derived for intermediate length chrysotile asbestos. The *Final LAA HHRA* presents three basic strategies available for estimation of the oral slope factor for asbestos:

- **"Epidemiological studies of cancer risk associated with exposure to asbestos in drinking water.** None of the available epidemiological studies of cancer risk in humans exposed to asbestos in drinking water are suitable for estimating quantitative dose response relationships (EPA, 1988b; ATSDR, 2001b).
- **Extrapolation from studies of workers exposed by inhalation.** Both EPA and the National Academy of Sciences sought to estimate the risk of gastrointestinal cancer after oral exposure by extrapolating dose-response data from occupational studies (EPA, 1980; NAS, 1983). However, these potency estimates are rather uncertain because of uncertainty both in the level of inhalation exposure and in the extent of transfer of fibers from the lung to the gastrointestinal tract, and this method for quantification of oral risk is not considered reliable (EPA, 1988b).
- **Extrapolation from animal studies.** EPA (1988b) determined that the most reliable study for estimation of oral cancer risk was the data on benign intestinal polyps in male rates exposed to intermediate length chrysotile (NTP, 1985). Based on the data from this study, EPA (1988b) calculated an upper bound on slope (q1*) of 1.4E-13 $(TEM\ fibers\ per\ liter\ [f/L])^{-1}$. Based on this, ingestion of 2 liters per day (L/day) of drinking water containing 1.0 MFL would result in an increased cancer risk to humans of about 1.4E-07. This corresponds to an oral slope factor of 7.0E-08 per million fibers ingested." (EPA, 2015a)

"The carcinogenic response in male rats exposed to intermediate range chrysotile was used by the EPA to derive the MCL for asbestos in water. It is important to note that the derived oral slope factor has not been approved for use at Superfund sites, and EPA's IRIS does not identify any quantitative value for evaluation of oral exposure to asbestos." (EPA, 2015a) Moreover, all studies of oral exposure to amphibole asbestos were negative for carcinogenicity. Refer to the Appendix A of the *Final LAA HHRA* for a comprehensive discussion on the screening level assessment of risks from oral exposure to LAA.

7.2.1.2 Non-Cancer Effects

"Non-cancer effects from asbestos exposure include asbestosis (formation of scar tissue in the lung parenchyma) and several types of abnormalities in the pleura (the membrane surrounding the lungs), such as pleural effusions (excess fluid accumulation in the pleural space), pleural plaques (collagen deposits and calcification), and pleural thickening.

Non-cancer hazard from inhalation exposure is determined based on a reference concentration (RfC) value. The RfC is an estimate (with uncertainty spanning an order of magnitude) of a continuous inhalation exposure that is likely to be without an appreciable risk of deleterious effects in humans (including sensitive subgroups) during a lifetime (EPA, 2009d). The LAA-specific RfC, referred to as RfC_{LA}, is derived from a group of workers employed at the O.M. Scott Plant in

Marysville, Ohio. This plant utilized vermiculite that originated from the mine in Libby from 1959 to 1980 in their lawn care products. Localized pleural thickening was selected as the critical effect endpoint for the derivation of the RfC_{LA}. The RfC_{LA} is 0.00009 PCM f/cc (EPA, 2014b)." (EPA, 2015a)

However, "studies in humans and animals indicate that ingestion of asbestos causes little or no risk of non-carcinogenic injury. Because ingested asbestos fibers are poorly absorbed, the tissue most highly exposed to ingested asbestos is the gastrointestinal tract epithelium. A few studies reported some histological or biochemical changes in gastrointestinal tract cells of rats chronically exposed to oral doses of asbestos, but, in an extensive series of lifetime dietary exposure studies in rats and Syrian hamsters, comprehensive microscopic evaluation of tissues and organs found no excess non-neoplastic lesions in the gastrointestinal epithelium or in other tissues or organs in animals exposed to daily doses as high as 500 to 830 milligrams of asbestos per kilogram body weight per day (mg/kg/day). The weight of evidence indicates that asbestos ingestion does not cause any significant non-carcinogenic effects in the gastrointestinal tract or other tissues." (EPA, 2015a) Refer to the Appendix A of the *Final LAA HHRA* for a comprehensive discussion on the screening level assessment of risks from oral exposure to LAA.

7.2.2 Exposure Assessment

Conceptual Site Model. **Figure 2-12** is an adaptation of the CSM developed for the *Final LAA HHRA* and presents the CSM for human exposure to LAA specific to the OU3 Study Area. The CSM presents in graphical form how LAA in source media from the OU3 Study Area could be transported in the environment to exposure media that humans may encounter. The primary exposure media within the OU3 Study Area is outdoor air.

7.2.2.1 Exposure Parameters

The risk assessment evaluates potential inhalation exposures for several receptor populations, including recreational visitors, USFS workers, USFS fire fighters, commercial loggers, and trespassers. Receptor-specific exposures are computed for exposure scenarios consistent with each receptor population. "Exposure estimates in the risk assessment do not seek to evaluate exposures for specific individuals." (EPA, 2015a) Rather, exposure estimates are calculated for representative members of the receptor population, calculating exposures based on both "typical" levels of exposure and "high-end" exposures. "These two exposure estimates are referred to as central tendency exposure (CTE) and reasonable maximum exposure (RME), respectively." (EPA, 2015a)

"For each exposure scenario evaluated in the risk assessment, information on estimated exposure time (ET, in hours per day), exposure frequency (EF, in days per year), and exposure duration (ED, in years) is used to derive a lifetime time-weighting factor (TWF) as follows:

$$TWF = (ET/24 \cdot EF/365 \cdot ED/70)$$

The value of the TWF ranges from zero to one, and describes the average fraction of a lifetime during which the specific exposure scenario occurs." (EPA, 2015a) The use of a TWF is consistent with the underlying basis for the IUR_{LA} and the RfC_{LA}, both of which are based on lifetime exposures. For each exposure scenario, TWFs are computed for both CTE and RME exposures.

7.2.2.2 Exposure Point Concentrations

An exposure point concentration (EPC) is an estimate of the concentration of a constituent (LAA) that a receptor may be exposed to under a specific exposure scenario. In the case of LAA, the EPC is a concentration of LAA fibers in air (PCME LAA s/cc). A reliable method to predict LAA levels in air based on measured LAA levels in source media (e.g., soil, duff, etc.) is not currently available. For this reason, the EPA recommends an empirical approach for estimating EPCs at asbestos-contaminated Superfund sites, where concentrations of asbestos in air resulting from activities that disturb source media are measured rather than predicted (EPA, 2008g). This type of sampling is referred to as activity-based sampling (ABS).

To date, eleven different ABS investigations have been conducted at the OU3 Study Area to estimate representative EPCs of LAA from various activities that disturb source media. These studies have included a wide range of activities that are typical of the defined receptor populations, including, but not limited to, riding all-terrain vehicles (ATVs), hiking, driving, residential wood harvesting, commercial logging, USFS activities (e.g., fighting fires and performing forest maintenance and surveying activities). In total, 700 ABS air samples have been collected within the OU3 Study Area since 2007.

In addition to ABS sampling, nearly 100 outdoor ambient air samples and over 75 perimeter air samples have been collected for the OU3 Study Area. Ambient air samples differ from ABS samples because they are designed to measure LAA in air absent any specific source media disturbance activity. Perimeter air samples were taken during the slash pile burn and prescribed understory burn ABS events to quantify the concentration of LAA in air at varying distances and directions before, during, and after ABS activities in the forested area.

“All ABS and ambient/perimeter air samples have been analyzed by TEM. During the analysis, detailed information for each observed asbestos structure (e.g., asbestos type, structure type, length, width) is recorded. For the purposes of computing risk estimates, it is necessary to” (EPA, 2015a) convert the TEM analysis results to estimates of “what would have been detected had the sample been analyzed by PCM.” (EPA, 2015a) This conversion is necessary because the IUR_{LA} and the RfC_{LA} were derived from studies in which PCM was the primary method for LAA analysis. “For convenience, structures detected under TEM that meet the recording rules for PCM are referred to as PCM-equivalent (PCME) structures. TEM analysis results for air samples are expressed as PCME LAA structures per cubic centimeter of air (s/cc).” (EPA, 2015a)

Typically, multiple measurements of LAA in air are determined for each ABS scenario. This results from the collection of multiple samples during an ABS event, the conduct of replicate ABS sampling events, or both. In accordance with the EPA asbestos risk assessment guidance (EPA, 2008g), EPCs for each exposure scenario are calculated as the arithmetic mean of all scenario-specific air sampling measurements, evaluating non-detect samples at a concentration value of zero. In some cases, air sampling filters were indirectly prepared for TEM analysis and an adjustment factor was applied before including the concentration in the calculation of arithmetic mean. As described in **Section 3.5.1**, the EPA’s site-specific adjustment factor of 2.5 was used for PCME LAA for indirectly prepared samples to account for the probable bias introduced through the indirect preparation technique. The derivation and use by the EPA of the adjustment factor of 2.5 in the *Final LAA HHRA* is described in Appendix D of the *Final LAA HHRA* (EPA, 2015a).

7.2.3 Risk Characterization

"The basic equation used to estimate excess lifetime cancer risk from inhalation of LAA is:

$$Risk = EPC \cdot TWF \cdot IUR_{LA}$$

where:

Risk = Lifetime excess risk of developing cancer (lung cancer or mesothelioma) as a consequence of LAA exposure.

EPC = Exposure point concentration of LAA in air (PCME LAA s/cc). The EPC is an estimate of the long-term average concentration of LAA in inhaled air for the specific exposure scenario being assessed.

TWF = Time-weighting factor which represents the fraction of a lifetime involved in the specific exposure scenario being assessed.

IUR_{LA} = LAA-specific inhalation unit risk (0.17 PCM s/cc)$^{-1}$

The basic equation used for characterizing non-cancer hazards from inhalation exposures to LAA is as follows:

$$HQ = EPC \cdot TWF / RfC_{LA}$$

where:

HQ = Hazard quotient for non-cancer effects from LAA exposure

EPC = Exposure point concentration of LAA in air (PCME LAA s/cc)

TWF = Time-weighting factor

RfC_{LA} = LAA-specific reference concentration (0.00009 PCM s/cc)" (EPA, 2015a)

7.2.4 Results

The Libby Site risk assessment characterizes risks to people from exposure to LAA at the OU3 Study Area to help risk managers determine if remedial actions are necessary to address risks, and if so, which exposure scenarios would need to be addressed in future remedial actions. Sections 5, 6, and 8 of the *Final LAA HHRA* present discussions specific to OU3 Study Area media and risks from exposures to these media, refer to Tables 5-1 through 5-4, 6-16 through 6-17, and 8-1 through 8-6 of the *Final LAA HHRA* included in **Appendix K**. Results of the risk assessment are intended to help inform the OU3 site manager and the public about the magnitude of potential risks attributable to LAA and to guide the selection of final remedial actions for the OU3 Study Area. The exposure scenario-specific risks, cumulative risk, and LAA HHRA uncertainty assessment from the *Final LAA HHRA* are presented below.

7.2.4.1 Exposure Scenario-Specific Risks

In total, more than 150 different exposure scenarios were evaluated in the risk assessment. For a given exposure scenario, non-cancer HQs can exceed 1 even when cancer risks are less than 1E-04, which indicates that non-cancer exposure is a more sensitive metric of potential concern. For LAA, EPA has determined that a non-cancer HQ of 1 is approximately equivalent to a cancer risk of 1E-05. The estimated RME cancer risks for all exposure scenarios at the OU3 Study Area are less than 1E-04.

There were very few exposure scenarios that, when considered alone, yield RME non-cancer HQs that exceed 1. Those that did were conducted under conservative scenarios (e.g., ABS conducted during dry weather conditions with conservative exposure scenarios) and were located in the Former Mine Area. These exposure scenarios are shown in **Figure 7-1** and listed from highest to lowest HQ. **Figure 7-1** compares the HQ values for OU3 Study Area scenarios with scenarios for other OUs to consider cumulative risks as discussed below. The exposure scenarios exceeding an HQ of 1 related to the OU3 Study Area are presented below:

- Outdoor worker exposures during commercial logging activities in OU3 near the mine (approximately 1 mile from the Former Mine Area center), especially those logging activities that disturb soil and duff material (e.g., site restoration, skidding) (HQ=2 for site restoration; HQ=5 for skidding);
    - Time-weighting factor for both activities was conservatively based on an ET= 10 hours per day, EF=24 days per year, and an ED=12 years.
- Firefighter exposures while performing dry mop-up activities after an understory burn that occurs near the mine (approximately 1 mile from the Former Mine Area center) (HQ=5);
    - Time-weighting factor for this activity was conservatively based on an ET=2 hours per day, EF=7 days per year, and an ED=25 years.
- Forest worker exposures while building slash piles near the mine (approximately 1 mile from the Former Mine Area center) (HQ=2);
    - Time-weighting factor for this activity was conservatively based on an ET=8 hours per day, EF=10 days per year, and an ED=10 years.
- Trespasser rock hound exposures in the disturbed area of the mine in OU3 (HQ=2);
    - Time-weighting factor for this activity was conservatively based on an ET=6 hours per day, EF=3 days per year, and an ED=52 years.
- Residential exposures (outside of OU3 Study Area) during woodstove ash disturbances (i.e., while emptying ash from the woodstove and then using a soft-bristled brush to sweep up and gather any additional ash material) when firewood is collected from near the mine (approximately 1 mile from the Former Mine Area center) (HQ=2).
    - Time-weighting factor for this activity was conservatively based on an ET= 0.25 hours per day, EF=48 days per year, and an ED=52 years.

7.2.4.2 Cumulative Risk

Most people who live or work in Libby or Troy may be exposed to LAA by a combination of the exposure scenarios described above and shown in **Figure 7-1**. “Consequently, it is important to estimate the total (cumulative) risk to a receptor that is exposed to multiple scenarios over their lifetime. The calculation of cumulative risk is complicated by the fact that the exposure pattern of

each individual at the Site may be unique. However, the EPA does not typically perform risk calculations for specific individuals, but rather for generic classes of receptor populations with common exposure patterns. Thus, the goal of the cumulative risk assessment is to characterize how cumulative risk depends on different types of disturbance activities, LAA levels in the source media, and exposure locations." (EPA, 2015a) Typically, if an HQ is less than or equal to 1, then remedial action is generally not warranted (EPA, 1991). However, to ensure protectiveness in consideration of potential cumulative exposures, EPA determined that an HQ of 0.6 is the appropriate threshold for frequently used residential properties within OU4 (EPA, 2016; CDM Smith, 2015b). In other words, EPA determined that cumulative risks can be mitigated by addressing individual risk drivers that have an HQ greater than 0.6.

Figure 7-1 includes the calculated risk drivers for both the OU3 Study Area and the other OUs in order to illustrate the individual risk drivers with an HQ of 0.6 or greater across the Libby Asbestos Superfund Site. It is important to note that the calculated HQ for OU4 background soils resulted in an ABS HQ value of 0.6 (shown in **Figure 7-1** as the Background OU4 "Bucket of Dirt" ABS result). This result provides a line-of-evidence that a HQ threshold of 0.6 is conservative because it is representative of background conditions in OU4, and CERCLA generally does not require cleanup to below background levels (EPA, 2002b). The appropriate remedial criteria for the OU3 Study Area will be evaluated during the FS and established in the ROD.

There are a large number of possible exposure scenario combinations that could be evaluated in the cumulative risk assessment for the Site. The choice of which combinations to evaluate is a matter of judgment. The *Final LAA HHRA* presents several alternative cumulative exposure scenario combinations representing a wide range of potential cumulative risks. These examples help to identify which exposure scenarios that tend to have the largest contribution to cumulative risk.

The cumulative risk calculations demonstrate:

- People who are predominantly exposed at properties and in locations where steps have been taken to limit potential exposures to LAA (e.g., exterior soil removals, interior vermiculite insulation removals, and cleanings have been completed or deemed not to be necessary) or at locations where lower LAA levels in source media (e.g., woodstove ash exposures when firewood is collected outside of approximately one mile from the center of the Former Mine Area, forest fire worker building slash piles at distances greater than 1 mile from the Former Mine Area center, outdoor worker firefighter during simulated burning activities) are likely to have cumulative risks that are below a level of concern, even when the cumulative scenario includes many different exposure activities across multiple OUs.
- Cumulative exposure and risk can be reduced by changing the locations where the activities are performed (e.g., collecting firewood from areas far from the mine site).
- Cumulative exposure has the potential to become significant if the majority of the receptor lifetime is spent at properties and in locations where LAA is present and where people are engaging in source disturbance activities that have a high potential for LAA releases.
- When cumulative exposure includes scenarios where LAA-contaminated source materials are disturbed, such as trespassing on the disturbed area of the mine site, disturbing surface soils with Bin B2/C concentrations, performing certain activities related to commercial logging operations near the mine site, disturbing vermiculite insulation during tradesperson activities, or disturbing subsurface soils with

residual LAA contamination, these exposures may be important risk drivers for cumulative risk estimates. The EPA defines a risk driver as an individual exposure scenario that contributes a substantial fraction of the cumulative risk (EPA, 2015a).

- It is not necessary to address every single exposure scenario to significantly lower cumulative HIs. Addressing exposures for the risk drivers will have the greatest impact in lowering cumulative exposures and risks.

7.2.4.3 LAA HHRA Uncertainty Assessment

Uncertainties exist in the *Final LAA HHRA* "due to limitations in the exposure and toxicity assessments and the ability to accurately determine cumulative exposure and risk from multiple sources over a lifetime." (EPA, 2015a) The *Final LAA HHRA* has used the best available science to evaluate potential human health exposures and risks from LAA at the OU3 Study Area; "however, there are number of sources of uncertainty that affect the risk estimates that must be considered when making risk management decisions. The most important of these uncertainties are listed below.

- Uncertainty in true long-term average LAA concentrations in air
- Uncertainty in the EPC due to non-detects
- Uncertainty due to air filter preparation methods
- Uncertainty due to analytical methods
- Uncertainty due to field collection methods
- Uncertainty in human exposure patterns
- Uncertainty in toxicity values used in risk characterization
- Uncertainty in the cumulative risk estimates

Because of these uncertainties, the cancer risks and non-cancer HQs for individual exposure scenarios are uncertain, and consequently all estimates of cumulative cancer risks and non-cancer HI values presented in the *Final LAA HHRA* are also uncertain, and should be considered approximate. Actual risks may be either higher or lower than estimated." (EPA, 2015a)

For a detailed discussion on each of the uncertainties listed above**,** refer to *Section 10 Uncertainty Assessment* of the *Final LAA HHRA* included in **Appendix K.**

7.3 ASBESTOS BASELINE ECOLOGICAL RISK ASSESSMENT

The purpose of the *Final Asbestos BERA* (EPA, 2014a) assessment was to describe the likelihood, nature, and extent of adverse effects on ecological receptors in the OU3 Study Area that result from exposure to LAA released to the environment as a result of past mining, milling, and processing activities at the OU3 Study Area. The *Final Asbestos BERA* (EPA, 2014a) assessment is discussed in further detail below with citations from the *Final Asbestos BERA* presented as quotations. The complete document is provided in **Appendix K.** Data used to support the *Final Asbestos BERA* have been collected as part of several investigations described in **Section 4.0**.

7.3.1 Conceptual Site Model

Figure 2-13 presents the CSM for exposure of each general ecological receptor group (fish, benthic macroinvertebrates, amphibians, aquatic plants, terrestrial plants, birds, mammals, soil

invertebrates, reptiles) to mining-related LAA releases at the OU3 Study Area as described in the *Final Asbestos BERA*. As shown, the following exposure pathways were evaluated quantitatively in the *Final Asbestos BERA*:

- Aquatic Receptors (fish, benthic macroinvertebrates, amphibians) – Direct contact exposures with sediment and/or surface water
- Wildlife Receptors (birds and mammals) – Exposures by four primary pathways
  1. Ingestion of LAA in or on dietary items
  2. Incidental ingestion of soil and/or sediment while feeding
  3. Ingestion of contaminated water
  4. Inhalation of LAA in air caused by current airborne emissions or disturbance during feeding, foraging, and nesting

7.3.2 Weight of Evidence Evaluation

In the *Final Asbestos BERA,* three different lines of evidence are presented:

- Site-specific toxicity tests,
- Population and community demographic observations, and
- In-situ measures of exposure and effects.

Each of these lines of evidence has inherent advantages and limitations. Therefore, the *Final Asbestos BERA* used a weight-of-evidence evaluation to develop risk conclusions, combining the findings across each line of evidence and taking the relative strengths and weaknesses of each line of evidence into account.

The weight of evidence risk conclusions and confidence in these conclusions are summarized below for each ecological group of interest at the OU3 Study Area. A result summary discussion for each line of evidence is provided in the *Final Asbestos BERA* included in **Appendix K**.

Fish. For fish, "the weight of evidence suggests that LAA in waters of LRC is not causing adverse effects on resident trout." (EPA, 2014a) By extension, since concentrations of LAA in the Kootenai River are substantially lower than in LRC, no studies were conducted on the effects of LAA on fish in the Kootenai River (including sensitive species such as the federally protected white sturgeon and bull trout) and, therefore, are not of concern. "Confidence in this conclusion is medium to high. The chief limitation to the in-situ exposure studies is that there is no control over environmental variables and the findings are limited to the conditions and concentration values that occurred during the studies (about 40-45 MFL for eyed eggs and about 10-30 MFL for juvenile trout). Consequently, if substantially higher concentrations were to occur in other years, the consequences, if any, cannot be predicted. In general, the chief limitation to fish population surveys is that population parameters and habitat variable often tend to be variable between years, making it difficult to distinguish between random and site-related differences. However, in this case, results were relatively consistent across two years, so confidence in these studies is good." (EPA, 2014a)

Benthic Macroinvertebrates. For benthic macroinvertebrates, the findings of the site specific sediment toxicity tests and the site-specific population studies "suggest that benthic macroinvertebrate communities along LRC may rank as slightly impaired compared to off-site reference locations, but are not impaired compared to URC. The differences are not extensive and might be due, at least in part, to differences in habitat quality. Taken together, these findings

support the conclusion that LAA in LRC may be causing small to moderate effects on survival of some species, but that the overall benthic macroinvertebrate community is not substantially impacted. Confidence in this conclusion is medium to high. One potential limitation to the site-specific studies is that the test species (*H. azteca* and *C. tentans*) are not expected to occur in mountain streams, and native species (mainly mayflies, stoneflies, caddisflies, true flies, and beetle larvae) might have differing sensitivities. While benthic community and habitat surveys often display considerable variability between years, in this case the results are relatively consistent between two years, providing good confidence in the survey results." (EPA, 2014a)

Amphibians. For amphibians, the findings of the site-specific sediment toxicity test and the survey of external and histological lesions in field-collected organisms support the conclusion that "sediments and waters in OU3 are not likely to be causing any ecologically significant adverse effects on amphibian populations" (EPA, 2014a) given a lack of overt signs of toxicity. The presence of an apparent lag time for metamorphosis in the laboratory study was determined by the laboratory study director to be a statistical artifact, and speculated that there would be no adverse effects from this finding to wild populations given natural plasticity in timing of metamorphosis and the presence of metamorphosed individuals found in the Site ponds. "Confidence in this conclusion is medium to high. The most significant uncertainty is whether the apparent delay in the final stages of metamorphosis might be of concern. Further studies would be need to determine if the apparent lag in final stage development is reproducible, and whether complete metamorphosis is ultimately achieved in exposed organisms." (EPA, 2014a)

Mammals. For mammals, there was one line of evidence available to evaluate risks from LAA exposure, an evaluation of lesion prevalence and severity in mice captured from the OU3 Study Area compared to mice from a reference area. "This is considered to be a relatively strong line of evidence because a) mice are likely to have high exposure to LAA in duff material and soil, b) the area selected for study was at the high end of LAA contamination observed in duff material, and c) the mice collected would have been exposed by all relevant exposure routes (inhalation, ingestion of soil, ingestion of food items)." (EPA, 2014a) Although the prevalence or mean severity of some types of lesions was higher in mice from the OU3 Study Area than the reference area, none of the lesions were judged to be associated with LAA exposure. They were instead attributable to normal parasitism or diseases common to wild mice. Moreover, none were judged to be associated with significant decrements to overall animal health, and no evidence of meaningful differences in body size or age of the mice was detected. Based on these results, "it is considered likely that LAA exposures in OU3 are not causing any ecologically significant effects on populations of small mammals residing in the forest areas OU3." (EPA, 2014a)

"Confidence in this conclusion is high. However, there are several uncertainties in extrapolation of the results from this study to other mammals that may be exposed in OU3, including the following:

- Larger mammals generally have longer life spans than mice, and consequently might have higher cumulative exposures than mice. Because effects of inhalation exposure to asbestos are usually found to be related to cumulative exposure in humans and laboratory animals (ATSDR, 2001a), this raises the possibility that risk of effect might be higher in larger mammals with longer lifespans than mice. However, numerous studies have shown that while effects of asbestos exposure in humans usually take many years to develop, the same effects occur in rats and mice within 1-2 years (ATSDR, 2001a). Moreover, home range is often much larger for large mammals than small mammals, so longer-lived species such as deer, elk, bear, lynx, etc., would generally be expected to spend only a fraction of their

lifespan in areas near the mine, thereby reducing their tendency for exposure. Although uncertain, there is no compelling evidence to presume that mammals with longer life spans than mice would likely be more at risk than mice.

- The mice that were evaluated were trapped in an area near the Former Mine Area where concentration levels of LAA in duff material are at the high end of the range that has been observed in the forest area. However, LAA levels on the Former Mine Area site itself are likely higher due to the presence of LAA veins in the ore body as well as in waste rock and tailing areas onsite. Consequently, mammals residing in the mined area (as opposed to the forest area around the mine) may have higher exposures." (EPA, 2014a)

Birds. There was one line of evidence available to evaluate the effect of LAA exposure on birds exposed in the OU3 Study Area, a literature-based evaluation of the relative sensitivity to the effects of inhaled particulates in birds compared to mammals. "Based on the available information, it is concluded that birds are not more sensitive, and are probably less sensitive, to the effects of inhaled particulates than mammals. Because a site-specific study of the effects of LAA on small mammals did not detect any evidence for increased incidence or severity of asbestos-related lesions in the respiratory tract, it is concluded that ecologically significant adverse effects are not likely to be of ecological concern in populations of birds exposed to LAA in OU3. Although a comparable comparative study was not attempted with regard to relative sensitivity by the oral exposure route, because no effects were noted in the gastrointestinal system of mice exposed in the OU3 Study Area, there is no reason to expect that effects in the gastrointestinal system of birds would be of concern. Confidence in this conclusion is medium. However, in the absence of direct studies of birds from the OU3 Study Area, several possible uncertainties remain including the following:

- The relative LA exposure levels of birds compared to mice in OU3 is not certain. It is assumed that of the wide variety of bird species that occur in OU3, ground foraging birds with small home ranges would tend to be most exposed, both by inhalation of fibers released to air and by ingestion of prey or food items capture in duff or soil. However, considering that mice are likely exposed nearly continuously in the duff or soil, while birds are likely to be exposed only while foraging, and would likely have low exposure while in trees or bushes, it is considered likely that birds are not more exposed, and might be less exposed, than mice.
- Much of the available information on the relative effects of inhaled particulates in birds is derived from studies of domestic poultry (chickens, ducks). In general, wild birds tend to be more robust than domestic fowl, which would tend to decrease sensitivity (Wideman, 2011). However, if effects on respiratory function do occur in wild birds, they might have larger consequences than observed in domestic fowl due to the higher demands on respiratory function during migration. Noting that these two uncertainties could influence risk estimates in opposite directions, and that migratory birds are likely to have lower exposures than resident birds, the conclusion that birds are not likely to be more sensitive than mammals is considered to be reliable." (EPA, 2014a)

7.4 NON-ASBESTOS BASELINE HUMAN HEALTH RISK ASSESSMENT

The purpose of the *Final Non-Asbestos HHRA* document is to quantify potential human health risks from exposures to non-asbestos COPCs at the OU3 Study Area under current and future conditions. The *Final Non-Asbestos HHRA* (CDM Smith, 2013a) assessment is discussed in

further detail below with citations from the *Final Non-Asbestos HHRA* presented as quotations. The complete document is provided in **Appendix K**. Data used to support the *Final Non-Asbestos HHRA* for the OU3 Study Area have been collected as part of several investigations described in **Section 4.0**.

7.4.1 Basis for Concern

"Although LAA is the primary concern at the Libby Site, other constituents (mainly metals)" naturally "present in the ore body may also have been released to the environment as a result of past mining and milling activities. In addition, other chemicals such as foaming agents, petroleum products, herbicides, pesticides, and PCBs may have been used or released during mining and milling operations within OU3." (CDM Smith, 2013a)

7.4.2 Conceptual Site Model

Figure 2-14 presents a CSM for human exposure to non-asbestos contaminants at the OU3 Study Area. The model presents in graphical form the ways in which materials released during mining operations might be contacted by people that use the OU3 Study Area.

Under current conditions in the OU3 Study Area, a range of different human receptors may be exposed to COPCs in the OU3 Study Area, including:

- Recreational visitors along streams and ponds
- Recreational visitors in the forested area
- Wood cutters and USFS workers in the forested area
- Trespassers in the Former Mine Area

At present, there are no groundwater wells in the OU3 Study Area that are used for drinking water. However, use of groundwater for drinking water by recreational visitors or workers might occur in the future, so this pathway is also of potential concern.

The OU3 Study Area does not include residential exposure scenarios. This is because any properties geographically within the OU3 Study Area that are currently residential (e.g., homes, yards, other frequently used areas) will be evaluated as part of OU4. Based on currently available information, future residential development is not reasonably anticipated in other areas of the OU3 Study Area (CDM Smith, 2013b).

7.4.3 Constituents of Potential Concern

EPA has performed several rounds of sampling and analysis to characterize the levels of non-asbestos contaminants in environmental media in the OU3 Study Area, including soils in the Former Mine Area, surface water and sediment in the OU3 Study Area streams and ponds, and groundwater from existing wells in the Former Mine Area. "Because non-asbestos data were not available for forest soils near the Former Mine Area, data from the Former Mine Area were used as a conservative surrogate for this medium.

The data were used to identify non-asbestos COPCs by comparing the maximum detected concentration for each constituent in each environmental medium to an appropriate risk-based concentration (RBC). If the maximum value exceeded the RBC, the constituent was retained as a COPC for that medium. Otherwise, the constituent was excluded as a COPC for that medium.

Implementation of this selection process lead to the identification of the following non-asbestos COPCs per medium:

- Surface water - manganese, fluoride, benzene
- Sediment - arsenic, cobalt, iron, manganese, thallium
- Groundwater - iron, manganese
- Soil (based on mined materials and soils in the Former Mine Area)
- Ingestion: arsenic, cobalt, thallium, benzo(a)pyrene
- Inhalation: aluminum, arsenic, barium, cobalt, manganese, nickel
- Fish - no COPCs identified" (CDM Smith, 2013a)

7.4.4 Toxicity Assessment

"All toxicity values used to characterize risk were selected in accordance with the EPA established hierarchy, preferring values that are listed in EPA's IRIS. If values were not available from IRIS, then the next preference was to seek Provisional Peer Reviewed Toxicity Values for Superfund (PPRTVs) developed by EPA's Superfund Health Risk Technical Support Center. If PPRTVs were not available, toxicity values were obtained from other sources, such as the ATSDR minimal risk levels (MRLs), California EPA Toxicity Criteria Database, and the EPA Health Effects Assessment Summary Tables (HEAST)." (CDM Smith, 2013a)

7.4.5 Exposure Assessment

The following exposure scenarios for the *Final Non-Asbestos HHRA* were evaluated quantitatively:

- Incidental ingestion of surface water and sediment from OU3 Study Area ponds and streams by recreational visitors
- Incidental ingestion of soil in the Former Mine Area by trespassers
- Incidental ingestion of soil in the forested areas surrounding the Former Mine Area by recreational visitors (hikers), wood cutters, and USFS personnel
- Inhalation of airborne particulates derived from soil in the Former Mine Area and soil in the forest areas during ATV riding
- Hypothetical future ingestion of groundwater from wells in the OU3 Study Area by recreational visitors

"Because no COPCs were identified for ingestion of fish, this pathway was not evaluated further.

Exposure was quantified using the standard equations recommended by the EPA for use at Superfund sites. Exposure parameters were based on the EPA default guidelines, or were based on professional judgment. For the purposes of this risk assessment, focus was placed on characterizing reasonable maximum exposure (RME), which is representative of the high-end of the range of exposures which may be possible. Exposure point concentrations were calculated from the data using EPA's ProUCL application to derive upper confidence limits (UCLs) on the mean concentration." (CDM Smith, 2013a)

7.4.6 Risk Characterization

Non-cancer and cancer risks were computed from the exposure estimates and the toxicity values in accordance with standard EPA equations (refer to Section 5.0 of the *Final Non-Asbestos HHRA* provided in **Appendix K**).

7.4.7 Results

Total risks to recreational visitors summed across all exposure media and COPCs show that non-cancer HIs are below a level of concern (less than 1) and cancer risks are usually below the lower end of EPA's acceptable risk range (less than 1E-06), both within and across exposure scenarios. Because the recreational visitor was the maximally exposed receptor, risks to wood cutters and USFS personnel from forest soil exposures would be even lower than those calculated for the recreational visitor. Based on these results, the EPA has concluded that human health risks from exposure to non-asbestos COPCs at the OU3 Study Area are likely to be below a level of concern (CDM Smith 2013a).

7.5 NON-ASBESTOS BASELINE ECOLOGICAL RISK ASSESSMENT

The purpose of the *Final Non-Asbestos BERA* was to describe the likelihood, nature, and extent of adverse effects on ecological receptors in the OU3 Study Area that result from exposure to non-asbestos constituents released to the environment as a result of past mining, milling, and processing activities at the OU3 Study Area (CDM Smith, 2013b). The *Final Non-Asbestos BERA* (CDM Smith, 2013b) assessment is discussed in further detail below with citations from the *Final Non-Asbestos BERA* presented as quotations. The complete document is provided in **Appendix K.** Data used to support the *Final Non-Asbestos BERA* for the OU3 Study Area have been collected as part of several investigations (refer to **Section 4.0**).

7.5.1 Basis for Concern

As noted above, although LAA is the primary concern at the Libby Site, other constituents (mainly metals) present in the ore body also may have been released to the environment as a result of past mining and milling activities. In addition, other constituents such as foaming agents, petroleum products, herbicides, pesticides, and PCBs may have been used or released during mining and milling operations within the OU3 Study Area.

The Former Mine Area is disturbed by past mining activity and some areas remain largely devoid of vegetation. Outside the Former Mine Area, most of the OU3 Study Area is forested, with Douglas fir and Lodgepole pine being the predominant species. The Former Mine Area is located within the Rainy Creek watershed, which includes several creeks and ponds, as well as the tailings impoundment. Various terrestrial and aquatic species are expected to occur at the OU3 Study Area, including several federally-listed and state species of concern.

7.5.2 Conceptual Site Model

Figure 2-15 presents the CSM for exposure of each general ecological receptor group (fish, aquatic invertebrates, amphibians, terrestrial plants, soil invertebrates, birds, mammals) to mining-related non-asbestos contaminants at the OU3 Study Area. "As shown, the following exposure pathways were evaluated quantitatively" (CDM Smith, 2013b) in the *Final Non-Asbestos BERA*:

- "Aquatic Receptors (fish, aquatic invertebrates, amphibians) – Direct contact exposures with sediment and/or surface water
- Terrestrial Plants and Soil Invertebrates – Direct contact exposures with soil
- Wildlife Receptors (birds and mammals) – Exposures by three primary pathways
  1. Ingestion of contaminants in or on dietary items
  2. Incidental ingestion of soil and/or sediment while feeding
  3. Ingestion of contaminated water" (CDM Smith, 2013b)

7.5.3 Constituents of Potential Concern

An initial HQ screen was completed as part of the *Final Non-Asbestos BERA*. The goal of the screen was to eliminate from further consideration any contaminants, media, or receptor groups for which the data indicate risks are clearly below a level of concern. Chemicals with concentrations above toxicity benchmarks were retained as COPCs for further evaluation in the refined HQ evaluation.

7.5.4 Risk Assessment Approach

"Three risk assessment evaluation strategies were used to evaluate risks for ecological receptors at OU3, the HQ approach, site-specific community evaluations, and site-specific toxicity tests. Each of these risk assessment evaluation strategies has advantages and limitations. For this reason, conclusions based on only one method of evaluation may be misleading. Therefore, the best approach for reaching reliable conclusions is to combine the findings across all of the methods for which data are available, taking the relative strengths and weaknesses of each method into account in a weight of evidence evaluation." (CDM Smith, 2013b)

7.5.5 Weight of Evidence Evaluation

In the *Final Non-Asbestos BERA* three different lines of evidence are presented:

- Refined HQ evaluations
- Habitat and community evaluations
- Site-specific toxicity test evaluations

The risk conclusions for each line of evidence, the confidence associated with each line of evidence, and the overall weight of evidence conclusion for each ecological receptor group of interest at the OU3 Study Area are detailed below.

7.5.5.1 Aquatic Receptors.

Fish. For fish, the weight of evidence suggests that risks from non-asbestos constituents in the OU3 Study Area are likely to be minimal. However, the fish community evaluation showed a lower fish density and decreased biomass in LRC relative to reference areas, which could be consistent with an assumption of non-asbestos COPC toxicity to trout. However, a number of the other lines of evidence for fish indicate otherwise (some of which became available after the *Final Non-Asbestos BERA* was prepared). For example, there are a number of habitat quality factors that correlate strongly with trout density suggesting that habitat is strongly influencing the apparent differences in fish density and biomass. In addition, an *in situ* stream toxicity study of early life stage (egg, hatched alevin) trout did not indicate any significant likelihood of population effects

from the small hatch reductions that were observed at the site (which included exposure to non-asbestos COPCs). Further, no effects that could contribute to decreased survival of larger fish were identified either in an *in situ* caged juvenile trout study or from gross examination of resident trout taken from the site stream; both of which included exposure to asbestos and non-asbestos COPCs. "For fish, the weight of evidence suggests that risks from non-asbestos constituents in OU3 are likely to be minimal." (CDM Smith, 2013b)

Aquatic Invertebrates. "For aquatic invertebrates, the community evaluations in Rainy Creek showed that the aquatic invertebrate community ranked as unimpaired to slightly impaired and habitat quality may be a contributing factor to any observed effects. Although HQ values suggest that risks to aquatic invertebrates from chromium, manganese, and nickel in sediment were possible" (CDM Smith, 2013b), the OU3 Study Area specific toxicity tests with *C. tentans* and *H. azteca* showed no adverse effects to growth and reproduction in exposed organisms and some slight impacts to survival. Results from the benthic community surveys conducted along LRC occasionally rank as slightly impaired compared with off-site reference creeks, but do not indicate impairment when compared to the on-site reference location (i.e., URC). The differences are not extensive and may actually reflect differences in habitat quality. "The weight of evidence suggests that risks from non-asbestos constituents in the OU3 Study Area are likely to be minimal." (CDM Smith, 2013b)

7.5.5.2 Terrestrial Plants and Soil Invertebrates.

"For plants and terrestrial invertebrates, the single line of evidence available (HQ) indicated that the potential for risk from several metals (barium, cobalt, nickel, vanadium) in the mined area cannot be excluded. However, due to the conservative nature of the toxicity benchmarks used in deriving HQ values, results should not be interpreted as evidence that risk does exist." (CDM Smith, 2013b)

7.5.5.3 Wildlife Receptors.

"For wildlife, the single line of evidence available (HQ) showed that risks to wildlife were either not expected or were likely to be minimal for nearly all COPCs for all receptors. The exception is potential risks to insectivorous wildlife from the ingestion of barium, manganese, and vanadium in aquatic invertebrates. The calculated HQ values are likely to be biased high and actual risks are likely to be lower" (CDM Smith, 2013b) due to conservative assumptions about bioaccumulation of metals through the food web. "Thus, results should not be interpreted as evidence that risk does exist." (CDM Smith, 2013b)